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KA-56 PANORAMIC CAMERA MODIFICATION

J. M. Daszkowski, et al

Fairchild Space and Defense Systems

Prepared for:

Rome Air Development Center

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August 1973

KA-56 PANORAMIC CAMERA MODIFICATION

Fairchild Camera & Instrument Corporation

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

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This report describes a research and development project which is contributing considerably to the future metric use of a rotary prism, moving film panoramic camera. It contains a detailed description of the necessary modifications which were implemented on the KA-56 Panoramic Camera, and discusses the technical advancements which were made during the design, development, fabrication, and testing of the miniature state-of-the-art, solid state flash fiducial film marking system. The metric use of the Fairchild KA-56

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20. ABSTRACT (continued)

Panoramic Camera has been investigated previously under the auspices of the Cooperative Research and Development Program between the Italian Air Force and the United States Air Force. The results of the investigation revealed that certain deficiencies exist in the camera system. These deficiencies are attributed to the fact that the camera, when designed, was never intended for metric use, and therefore, its physical geometry is not rigid enough. In order to overcome these deficiencies some modifications of the camera were necessary. These modifications had to be aimed at providing each frame of imagery with certain characteristic information pertinent to the orientation and operating position of the camera. On 16 May 1972 a research and development contract was awarded to FSDS to perform the necessary design feasibility studies and modifications on a government-furnished KA-56 panoramic camera. Implementation of the modifications resulting from the design feasibility study was completed by FSDS in February 1973. The implemented modifications provided each frame of imagery with the following recorded informations pertinent to the orientation and operating position of the sensor: (a) prism degree "fore" and "aft" fiducial marks recorded every 10 degrees of the scan; (b) center of scan identification mark; (c) timing fiducial mark recorded every 0.01 second; (d) lens position fiducial mark recorded simultaneously with the prism degree fiducials every 10 degrees of the scan. The fiducial marks recorded on the film negative have sufficient optical density and definition to reproduce on subsequent photographic reproductions. Feasibility of the Fairchild advanced modification design concept has been proven, flight testing is recommended.

KA-56 PANORAMIC CAMERA MODIFICATION

J. M. Daszkowski
E. J. O'Donnell
R. M. Sweet

Fairchild Camera & Instrument Corporation

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FOREWORD

This Final Report was prepared by the Fairchild Space and Defense Systems (FSDS), a Division of Fairchild Camera and Instrument Corporation at Syosset, New York, under contract F30602-72-C-0374, Job Order Number 55690243, for Rome Air Development Center, Griffiss Air Force Base, New York. Mr. John R. Callander (IRRG) was the RADC Project Engineer in charge.

Numbered by FSDS ED-AC-39, this report describes the engineering study, design, fabrication, and testing conducted between June 1972 and March 1973. Mr. Joseph M. Daszkowski was the principal investigator and Project Engineer for FSDS. Principal contributors to the design of the Solid State Flash Fiducial Film Marking System on the KA-56B Camera in addition to Mr. Daszkowski were Senior Staff Engineers, Messrs. Edward J. O'Donnell and Robert M. Sweet.

Appreciation is expressed to Mr. Callander for his helpful suggestions directing the effort toward more meaningful and useful results.

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

APPROVED: John R. Callander
JOHN R. CALLANDER
Project Engineer

APPROVED: Howard Davis
HOWARD DAVIS
Technical Director
Intel & Recon Division

FOR THE COMMANDER:
CARLO P. CROCETTI
Chief, Plans Office

ABSTRACT

This report describes a Research and Development Project which is contributing considerably to the future metric use of a rotary prism, moving film panoramic camera. It contains a detailed description of the necessary modifications which were implemented on the KA-56 Panoramic Camera, and discusses the technical advancements which were made during the design, development, fabrication, and testing of the miniature state-of-the-art, solid state flash fiducial film marking system. The metric use of the Fairchild KA-56 Panoramic Camera has been investigated previously under the auspices of the Cooperative Research and Development Program between the Italian Air Force and the United States Air Force. The results of the investigation revealed that certain deficiencies exist in the camera system. These deficiencies are attributed to the fact that the camera when designed, was never intended for metric use, and therefore its physical geometry is not rigid enough. In order to overcome these deficiencies some modifications of the camera were necessary. These modifications had to be aimed at providing each frame of imagery with certain characteristic information pertinent to the orientation and operating position of the camera. On 16 May 1972 a Research and Development Contract No. F30602-72-C-0374 was awarded to the FSDS to perform the necessary design feasibility studies and modifications on a government furnished KA-56 panoramic camera. Implementation of the modifications resulting from the design feasibility study, was completed by FSDS in February 1973. (The implemented modifications provided each frame of imagery with the following recorded informations pertinent to the orientation and operating position of the sensor: (a) prism degree "fore" and "aft" fiducial marks recorded every 10 degrees of the scan; (b) center of scan identification mark; (c) timing fiducial mark recorded every 0.01 second; (d) lens position fiducial mark recorded simultaneously with the prism degree fiducials every 10 degrees of the scan.) The fiducial marks recorded on the film negative have sufficient optical density and definition to reproduce on subsequent photographic reproductions. Feasibility of the Fairchild advanced modification design concept has been proven, flight testing is recommended.

EVALUATION MEMO

This report documents the work performed in the modification of the KA-56 aerial reconnaissance camera system to make the resultant imagery usable for photogrammetric targeting and related mapping functions. This represents a significant achievement with the marriage of miniaturized solid-state LED (light emitting diode) technology to the latest photogrammetric advances in the use of tactical reconnaissance camera system. The modifications made, provides each frame of imagery with: (a) angular prism marks every 10 degrees of the scan; (b) center of scan identification mark; (c) timing marks recorded every 0.01 second and (d) IMC trace synchronously with the 10 degree prism mark. It successfully demonstrates that such a modification can be made within the internal boundaries of the camera body. It also shows that such a modification does not detract from original camera performance characteristics but rather improves its utility for metric application.

Presently, plans are being made for the flight test of this system over the Casa Grande test range. A metric evaluation of the imagery will then be made to determine the improvement in its targeting characteristics. It is sincerely hoped these documented results would then serve as a future camera design standard to be used by the tactical reconnaissance community.

John R. Callander

JOHN R. CALLANDER
Phys Scientist

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SECTION I

INTRODUCTION

The objective of the Research and Development Project described herein was to modify one (1) KA-56 Panoramic Camera so that it would be more useful in the photogrammetric process. The modification design approach had to be applicable to both the KA-56 and KA-60C panoramic cameras but implemented on the KA-56 camera only. The modifications had to be aimed at providing each frame of imagery with certain characteristic information pertinent to the orientation and operating position of the sensor.

1.1 GENERAL BACKGROUND

Under the auspices of the Cooperative Research and Development Program between the Italian Air Force and the United States Air Force, the metric use of the KA-56 panoramic camera has been investigated. Techniques and computer programs have been developed for such photogrammetric operations as resection, intersection, relative orientation and strip triangulation. These techniques and computer programs have been tested with ficticious data and found to perform satisfactorily. However, the results of this testing revealed that certain deficiencies exist in the overall camera system. These deficiencies stem mainly from the fact that the camera, when designed, was never intended for metric use, and therefore, its physical geometry is not satisfactorily rigid. In order to overcome these deficiencies some modifications of the camera were necessary.

The KA-56 camera is a rotary prism, moving film type panoramic camera, utilizing a 75mm focal length, f/4.5 lens. The camera is provided with automatic exposure control (AEC) and image motion compensation (IMC). Panoramic film exposure is accomplished in the camera by continuously rotating a double dove prism in front of a lens on an axis of rotation parallel to the flight direction of the aircraft, while simultaneously advancing film past a narrow exposure slit at the focal plane. The film advance is synchronized with the prism rotation so that the image is "painted" on the film as the prism scans from horizon-to-horizon.

The prism assembly transmits to the lens a scan angle in excess of 180°. The angular velocity of scan is twice the angular velocity of the prism assembly. The mechanical scanning cycle is determined by the following conditions:

a. The prism assembly rotates 180° in one photographic cycle.

b. The IMC input shaft rotates 360° in one photographic cycle.

c. The film transport pucks, having a radius equal to the focal length of the lens (R = 2.943 ±.0015), revolve at a rate compatible with the scan velocity at the focal plane. They rotate 360° per one photographic cycle.

The camera operates in an autocycle mode with cycle rates continuously variable from 1 to 6 exposures per second. Shutter speeds of 1/500 second to 1/5000 second are obtainable in all variations of film velocity within the range of 18.49 to 110.94 inches per second. The principle of operation of the KA-60C camera is very similar and therefore will not be discussed herein.

1.2 FAIRCHILD RESPONSE TO RFP

The proposal No. ED-CB-179 for the study, design and modification of one (1) KA-56 panoramic camera has been prepared by Fairchild Space and Defense Systems in response to RFP F30602-72-Q-0209, dated 11 January 1972.

Contract No. F30602-72-C-0374 was awarded to the Fairchild Space and Defense Systems on 16 May 1972 to perform services and deliver to the Air Force one (1) modified KA-56 Panoramic Camera by modifying a government furnished KA-56 camera. The technical requirements for the modification were specified in paragraph 4.0 of the Statement of Work for Panoramic Camera Modification PR No. I-2-4039 dated 1971 October 26, and Amendment No. 1 dated 1972 April 10.

1.3 CONTRACT REQUIREMENTS

The basic itemized requirements of the contract were as follows:

Item 0001 Engineering services for System Design and Modification in accordance with paragraph 4.1, 4.2 and 4.3 of the Statement of Work.

Item 0002 Maintenance in accordance with paragraph 4.4 of Statement of Work. Not to exceed five (5) trips.

Item 0003 Data in accordance with Exhibit "A" (DD Form 1423) dated 1971 October 26, and Amendment No. 1 dated 1972 April 10.

1.4 APPLICABLE DOCUMENTS

The following documents were a part of the contract:

> Attachment No. 1, Statement of Work entitled "Panoramic Camera Modification" PR No. I-2-4039 dated 1971 October 26 and Amendment No. 1 dated 1972 April 10; Exhibit "A" entitled "Data", dated 1971 October 26 and attachment thereto "Contract Data Requirements List" (DD Form 1423) dated 1971 October 26.

1.5 CONTRACT SCHEDULES

Some of the more important contract schedules are listed in the following paragraphs:

1.5.1 Delivery

Item	Description	Quantity	Delivery	Prepaid to or FOB
0001	Engineering Services for system design modification.		Six (6) Months ARO	Contractor's facility Code: 72314
0002	Maintenance	Not to exceed five (5) trips	One (1) year maximum from the date of final acceptance.	Eglin AFB, Florida Code: FB2823
0003	Data	As shown on DD Form 1423		Destination as shown on DD Form 1423 Code: FQ7619

1.5.2 Inspection and Acceptance

The points of final inspection and final acceptance of all items required under the contract were those indicated below for each item:

Item		
0001	Contractor's Facility	RADC, Griffiss AFB, N.Y. 13440
0002	Eglin AFB, Florida	RADC, Griffiss AFB, N.Y. 13440
0003	RADC, Griffiss AFB, N.Y.	RADC, Griffiss AFB, N.Y. 13440

1.5.3 Special Provisions

a. Government Property. Subject to the provisions of the government property clause of the contract, the government was obligated to furnish the following listed property to the contractor, by the date(s) shown:

Property	Date
KA-56 Camera	One (1) week after award of contract.

b. Military Security Classification.

This contract had a security classification of UNCLASSIFIED.

c. Sponsoring Agency.

The sponsoring agency was: Air Force Systems Command, Rome Air Development Center, Griffiss Air Force Base, New York 13440.

SECTION II

IN-COMING INSPECTION AND TESTING

The government furnished KA-56 camera system components were received by FSDS on 21 June 1972 and immediately turned over to the Quality Control Department for incoming inspection. Their visual inspection revealed that the received camera system was a combination of the KA-56B and the KA-56D systems. The following components were identified as part of the KA-56B camera system:

Camera Body Assembly,	P/N 1076B200
Camera Control Unit,	P/N 1076E100
Film Cassette,	P/N 1076D100

The "In-Line" Magazine, P/N 1087B1, which is a part of the KA-56D camera system was also received. The "wrap around" magazine which is normally supplied with the "B" system was not received.

The inspection also revealed the following discrepancies:

Magazine,P/N 1087B1

1. Excessive clearance between the film keepers and sprockets.
2. One loop former spring was sluggish.
3. Film indicator arm was binding.
4. Magazine platen was coated with graphite, which is not a standard finish normally applied by Fairchild.
5. Film roller was binding.
6. Magazine needed thorough cleaning.

Camera Body, P/N 1076B200

1. Focal plane plate had burrs on the top surface and at the dowel pin.

2. Black anodized surface of the AEC plate facing the film emulsion had scratches.

3. Film guides on AEC plate were not polished.

4. Screw on micro-switch bracket was out of adjustment.

5. Locking nut was missing from set screw of the ADAS clapper assembly.

6. Glyptal was missing from several screws attaching the data tube holders and ADAS clamp eccentric. The optical system was out of alignment, producing unacceptable distortion.

7. Camera needed thorough cleaning.

8. A broken data recording mirror was discovered later during the disassembly of the camera.

The mechanical inspection report indicated that most of the above defects will contribute to film scratching; and the excessive clearance between the film keepers and sprockets may lead to film mistracking.

Most of these discrepancies were corrected and reinspected during the modification program without additional cost to the government.

The visual inspection was followed by the operational test and the dynamic resolution test. The camera system was connected to the power supply and operated from the controls of the Camera Control Unit and the Camera System Test Console. The operational and the resolution test revealed the following discrepancies:

1. Center of format light was not operating.

2. Camera cycling rate was slow; not to the specification.

3. Camera failed the dynamic resolution test.

A copy of the original incoming inspection report is included in Appendix I.

SECTION III

MODIFICATION DESIGN STUDY

This section describes the KA-56B and the KA-60C modification design study phase. The section contains: a detailed description of the main objectives and requirements; a discussion of the design problems and solutions, the preliminary accuracies assigned in the modification, and the outline of the design changes to be made during the modification.

3.1 OBJECTIVES.

The objectives of the modification design study were as follows:

1. To provide a common modification design concept which may be applicable to both cameras, with the provision that the actual modification will be implemented on the KA-56 camera only.

2. To determine preliminary accuracies involved in the modification before the final selection of the more expensive purchased components (i.e., optical encoder and oscillator).

3. To determine what design changes could be made to the existing parts and assemblies without disturbing the operational concept of the camera.

3.2 DESIGN REQUIREMENTS.

The design studies were aimed at providing each frame of imagery with the following characteristic information pertinent to the orientation and operating position of the sensor.

1. Prism degree marks placed on both (fore and aft) edges of the imagery so that skew in the film motion can be determined. These marks had to be recorded at a nominal 10° interval relative to the beginning of scan with an accuracy of 30 seconds of arc as a design goal.

2. Knowledge of the parallelism of the focal plane and the axis of rotation of the prism to an accuracy of ±30 seconds of arc as a design goal.

Similar knowledge of the divergence from a single vertical plane of the exposure slit and the prism axis of rotation. This information had to be gained through a calibration rather than a hardware modification to the camera.

3. Fiducial marks at the physical center of scan to be placed on both edges of the imagery, with an accuracy of ±20 micrometers as a design goal.

4. Knowledge of the position of the lens providing IMC during exposure of the imagery. The following three possible means of acquiring this knowledge were analyzed during the design studies: (a) construction of the lens mechanism so that its motion may be precisely represented by mathematical expression; (b) monitoring and recording incremental position of the lens during the exposure cycle and, (c) imaging on the film the actual position of the lens during exposure. If either of the first two means were employed, correlation or reference marks had to be recorded with an accuracy of ±20 micrometers.

5. Recording of timing marks on one edge of the format. Marks had to be placed on the film at discrete intervals of time to aid in the determination of image positions if the variations of the film velocity are known. These marks were intented to be used primarily to verify the constancy of the film velocity. The timing marks had to be recorded every 0.01 second with an accuracy of ±0.001 second relative to the time at the beginning of scan.

The "fiducial" flash system consisting of Items (1), (3), (4), and (5) had to be located at the focal plane with proper orientation to the film so that each event could be recorded in sequence on the edge of the format. The fiducial marks generated by this system on the film had to be of sufficient optical density and definition to reproduce on subsequent photographic reproductions.

The interface electronics had to be incorporated so that all components were internal to the camera system.

The modifications made to the camera had to operate under the service conditions identified in the latest KA-56 USAF camera production specifications.

3.3 DESIGN PROBLEMS AND SOLUTIONS.

The final flash fiducial system design concept evolved after a thorough analysis of the commonalities existing between the KA-56B and KA-60C camera was performed.

In addition to the "commonality analysis," an extensive study of the design requirements (tasks) listed in paragraph 3.2 was made. During this study particular attention was paid to design feasibility, simplicity, accuracy, reliability, and the cost factor.

In order to provide a less complicated and more accurate system two minor deviations to the paragraphs 4.2.1.1.2 and 4.2.1.1.3 of the Statement of Work were taken. Both deviations which are quoted in Section IV, paragraph 4.1, Specification Compliance, were approved by the RADC representatives during the design review.

During the design study every effort was made to arrive at the final design concept that would satisfy all the design requirements. A particular attention was given to several design problems which were encountered. Some of the more important problems and their solutions are described in the following paragraphs.

3.3.1 Location of Focal Plane Fiducial Projectors

One of the most important design requirements was that the film marking system had to be displayed over the entire film format with very high "design goal" accuracy. In order to achieve a full 180° format coverage, and to provide the desired accuracy of the recording, the focal plane flash fiducial projectors had to be placed at the center of the maximum opening of the exposure slit. This design requirement presented us with the problem which will be discussed herein.

If the projectors were placed at the offset position with respect to the exposure slit, some of the prism degree and lens position marks would not be recorded at either the beginning or the end of the film format depending on which side of the exposure slit the projectors were located. In addition, the recording accuracy of the entire display could not be determined closely because all fiducials would be flashed and recorded either before or after the ground scene was exposed on the film format. In order to provide the required space in which the focal plane fiducial projectors would be mounted, the exposure slit length was decreased from 4.500 inches to 4.188 inches. As a result of this change the film format width and the camera forward overlap value were reduced automatically. The new format width of 4.188 inches resulted in the reduction of the forward overlap from 56 percent to approximately 52 percent.

3.3.2 Knowledge of Lens Position

The optimum method of providing knowledge of the lens position during the panoramic scan had to be determined during the design study. The design study which included a thorough design analysis of the existing IMC and AEC systems, produced the following findings:

a. During the IMC stroke the lens does not translate along a straight line parallel to the direction of flight, but instead traverses an arc of 3.500 inches radius. This results in improper phasing of the IMC which in turn introduces errors in both the "X" and "Y" directions. The lateral error, depending on the scan angle, will reach on the film negative a nominal value of -0.0142 inch at the right horizon (0° scan angle) and +0.0142 inch at the left horizon (180° scan angle). The longitudinal error (error in the direction of flight) is very insignificant when compared with the lateral error and therefore will not be discussed herein.

b. The design analysis of the Automatic Exposure Control system revealed that the location of the leading stationary edge of the exposure slit is offset from the camera plane of symmetry by the nominal value of 0.100 inch.

The above findings automatically eliminated the design approaches contained in the FSDS Proposal No. ED-CB-179 (see paragraph 2.4.3, lens position) which were recommended for the evaluation during the design study. One approach was based on the static calibration of the position of the lens at the mid-point of scan combined with the mathematical expression for the movement of the lens during scan. The other approach was based on the projection of a fiducial mark representing the principal point. Since the lens-IMC mechanism did not provide a precise and rectilinear translation that could be represented by a mathematical expression, and since the offset position of the exposure slit prevented projection of the principal point both approaches had to be rejected and a new solution to the problem had to be found. A new approach developed during the study was based on the projection of a "lens position mark" which would represent a selected point located on the lens. Since the flash fiducial projector will be mounted directly on the lens cover attached to the lens barrel a predetermined number of the true lens positions can be recorded during the lens IMC movement. The fiducial mark

can be flashed at very small time intervals to produce an approximate [1] IMC trace (cosine curve) or flashed in synchronism with the prism degree marks every five (5) degrees of the prism rotation, to produce nineteen (19) fiducial marks. The final selection of the operating mode was left open to discussion during the design review.

3.4 PRELIMINARY ACCURACIES.

The preliminary accuracies assigned in the modification of the KA-56B camera were as follows:

1. Prism degree marks flashed during the photographic portion of the scan every five (5) degrees of the prism rotation with an accuracy of ±30 seconds of arc.

2. Timing marks flashed continuously every 0.01 second with an accuracy of ±0.0001 second.

3. Lens position mark flashed either continuously at very small time intervals to produce an "IMC trace," or flashed in synchronism with the prism rotation with an accuracy of ±30 seconds of arc.

4. Center of scan identification mark flashed at the center of scan in the vicinity of the 90° prism degree mark (close accuracy not required).

5. Parallelism deviations between the axis of rotation of the prism, the focal plane and the exposure slit to an accuracy of ±30 seconds of arc.

6. Important inspections during calibration to an accuracy of ±0.0002 inch (linear measurements) and ±30 seconds of arc (angular measurements).

[1] A true IMC curve can be generated only by the principal point translated rectilinearly during the IMC stroke.

3.5 DESIGN CHANGES.

At the conclusion of the design study phase the following outline of the necessary design changes (subject to RADC approval) was prepared:

1. Parts and assemblies to be removed and obsoleted:

Part No.	Nomenclature	Next Assy. No.
1076B121	Shield, Lens Assy.	1076B113
1076-1271	Screw, Machine Optical Assy.	1076B113
1076-1209	Plate	1076B113
1076-935	Lampholder	1076B200
1076B109	Harness Assy.	1076B200
1076-812	Aperture, Lampholder	1076B200
1076-83	Gasket	1076B200

2. Major assemblies to be modified:

Old Part No.	Nomenclature	New Part No.
1076B27	Prism Assy.	1253B12
1076B105	Body Boring & Painting Assy.	1253B25
1076B108	Wobble Plate Assy., IMC	1253B13
1076B113	Optical Assy., AEC	1253B2
1076B26	Holder Assy.	1253B11

3. Parts to be redesigned and replaced with the new parts of similar design:

Old Part No.	Nomenclature	New Part No.
1076-84	Cover, Access, Photocell	1253B23
1076-150	Bracket, Angle E.C.	1253-15
1076-259	Plate, Holding Mirror	1253-24
1076-261	Mirror	1253-23
1076-1162	Plate Set, Focal Plane	1253-9

4. Parts and assemblies to be reworked:

Old Part No.	Nomenclature	New Part No.
1076-372	Mounting Plate, Access Cover	1253-65
1076-915	Shutter	1253-22
1076-921	Counter-Weight	1253-53
1076-928	Body, Camera	1253-37
1076-941	Cover, Body	1253-38
1076-942	Plate, Mounting	1253-20
1076-1233	Shim, Focal Plane	1253-21
1076B26	Holder Assy., Optical Element	1253B11

The design changes listed above had no effect on the operational concept of the camera system. The final design approach applicable to both the KA-56B and KA-60C cameras, and the design changes affecting the KA-56B camera were documented in the preliminary set of layouts, which were approved by the RADC representatives during the design review meeting. Final set of design and assembly layouts in reduced format is presented herein in Appendix IV for reference only.

SECTION IV

DESIGN REVIEW

A design review meeting was held at the FSDS facility on 29 August 1972, during which the results of the KA-56B and KA-60C modification design studies were discussed with the RADC representatives. During the meeting several modification design layouts were reviewed and approved by the RADC representatives. It was agreed that only the Camera Body Assembly, Part Number 1076B200, Serial Number 65-2165 will be modified, while the Camera Magazine, Part Number 1078B1, Serial Number [illegible]-126 and the Camera Control Unit, Part Number 1076E100, Serial Number 65-625 will be used in the new camera system without modification.

4.1 SPECIFICATION COMPLIANCE.

The Government Representatives approved the following changes to the Statement of Work PR No. I-2-4039:

1. Recording of timing marks, paragraph 4.2.1.1.3

   Delete last sentence and substitute the following:
   "The timing marks shall be recorded every 0.01 second with an accuracy of ±0.001 second relative to the first timing mark. The first timing mark will be flashed within 0.01 second relative to the time at the beginning of scan."

2. Recording of the center of scan marks, paragraph 4.2.1.1.2

   Delete sentence and substitute the following:
   "An identification mark shall be flashed at the center of scan in the vicinity of the 90° prism degree mark."

4.2 RECORDING OF IMC TRACE.

An agreement was reached that the lens position mark will be flashed simultaneously with the prism degree marks, utilizing the same firing signal generated by the Incremental Optical Encoder.

A more detailed description of the meeting is included in Appendix II titled "Minutes of Design Approval Conference."

SECTION V

CAMERA MODIFICATION

This section defines all major components of the modified camera system. It contains a general description of the flash fiducial film marking system and a detailed description of the implemented modifications. The last paragraph of this section contains a description of the exposed film format; it defines the final accuracies achieved and compares them with the original design goal requirements.

5.1 CAMERA SYSTEM COMPONENTS.

The modified panoramic camera system (P/N 1253A1) consists of the following major camera system components:

a. <u>Camera Body Assembly, P/N 1253B1</u>

   (Former P/N 1076B200, Serial No. 65-2165)

b. <u>Camera Magazine Assembly, P/N 1087B, Serial No. 66-126</u>

c. <u>Camera Control Unit Assembly, P/N 1076E100, Serial No. 65-625</u>

The camera magazine and the camera control unit assemblies were not modified; they were tested however together with the modified camera body assembly during the final Acceptance Test.

The major camera body assembly components which were modified or added to the existing equipment are shown in Figure 1.

5.2 GENERAL DESCRIPTION OF FLASH FIDUCIAL FILM MARKING SYSTEM.

A block diagram illustrating the KA-56B camera modification is shown in Figure 2. The flash fiducial film marking system implemented on the KA-56B camera consists of the following major components, controls and circuits:

- Aft Fiducial Projector Assembly (See Figure 4, sheet 3 of 3.)

- Wobble Plate Assembly (See Figure 1, sheet 2 of 3.)

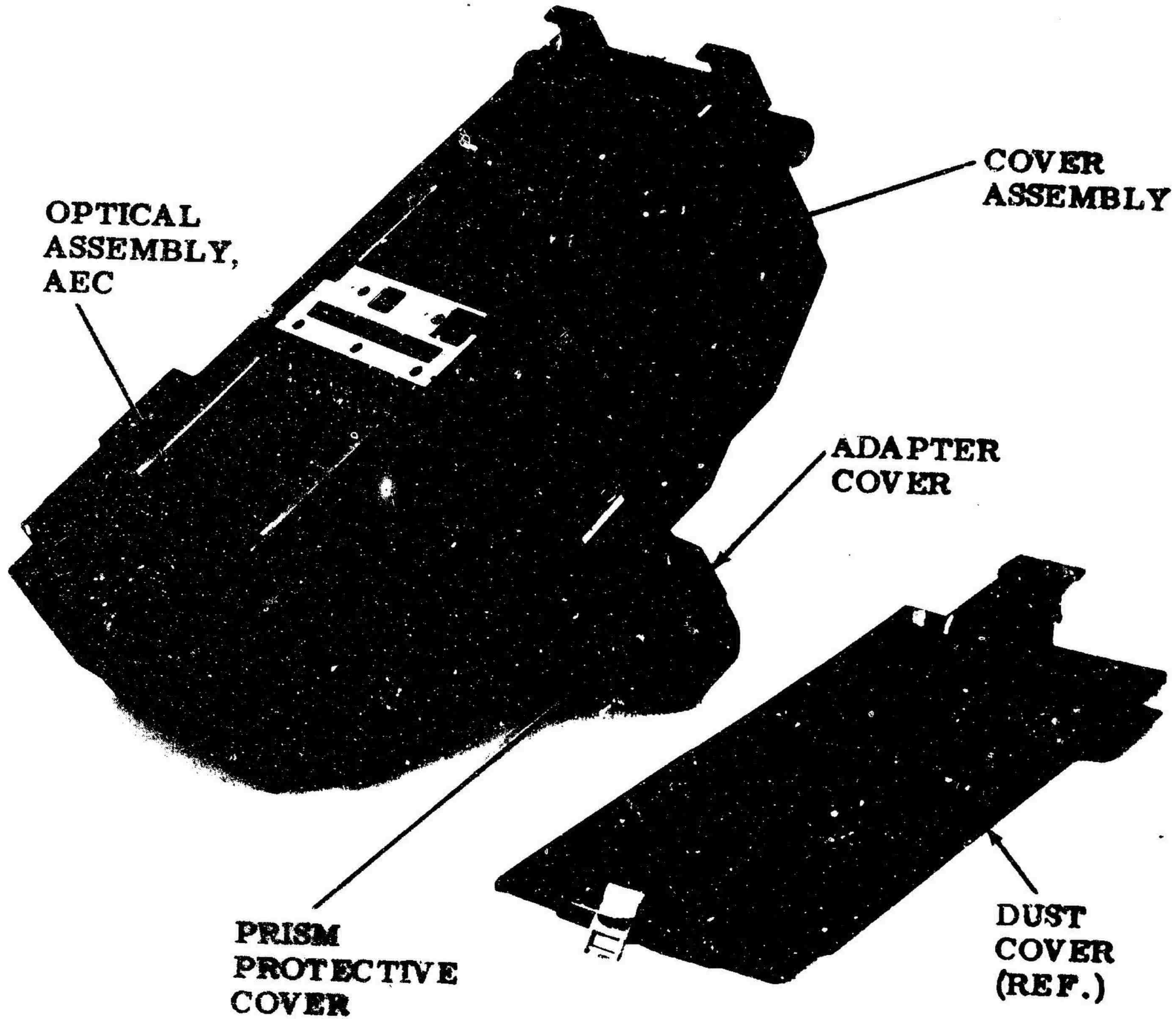


Figure 1. Camera Body Assembly (Sheet 1 of 3)

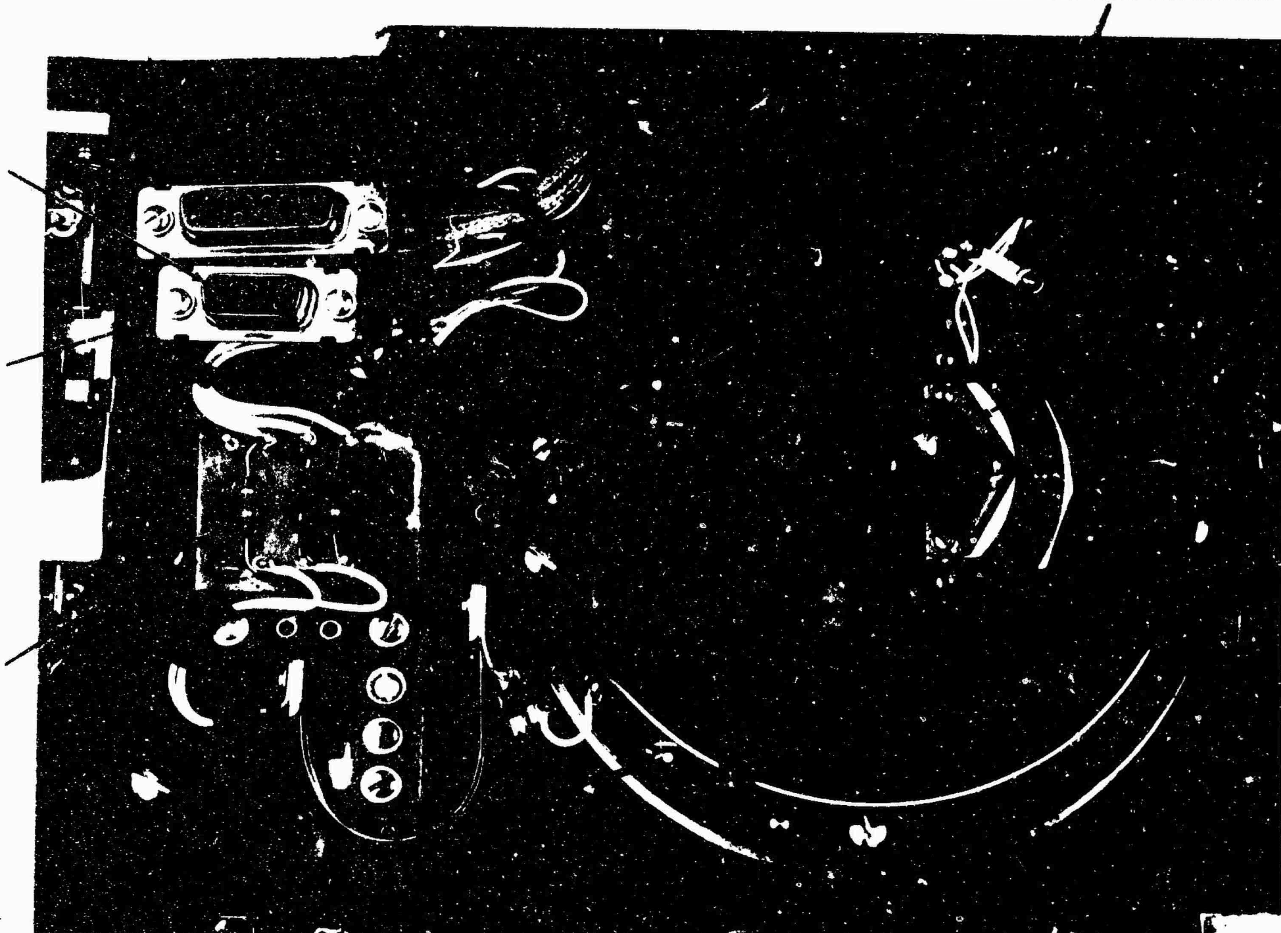


Figure 1. Camera Body Assembly (Sheet 1 of 3)

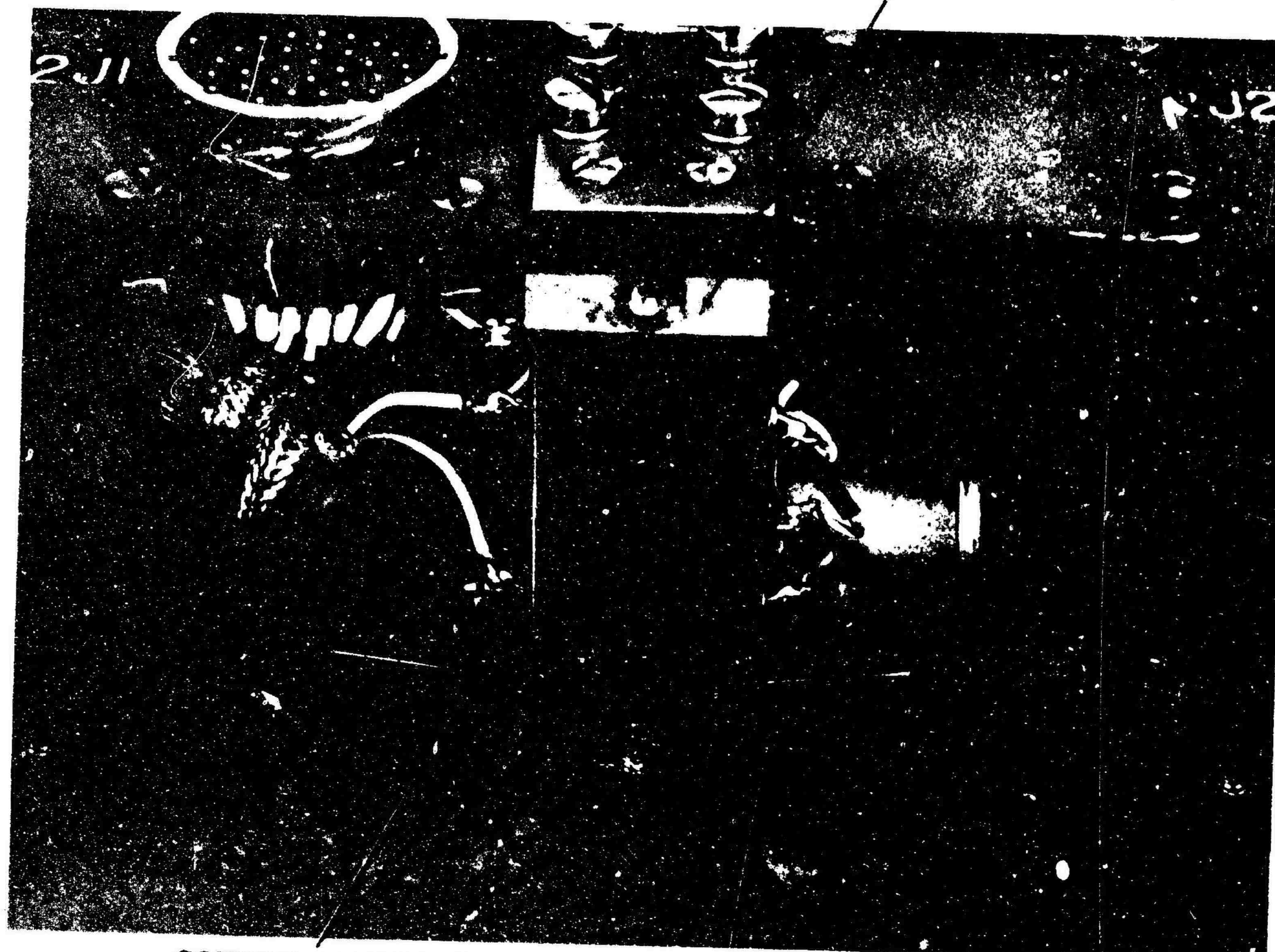


Figure 1. Camera Body Assembly (Sheet 3 of 3)

- Lens Cover Assembly (See Figure , sheet 2 of 3.)

- Lens Position Fiducial Projector Assembly (See Figure 1, sheet 2 of 3.)

- Flexible Conductor Assembly (See Figure 1, sheet 2 of 3.)

- Fore Fiducial Projector Assembly (See Figure 4, sheet 3 of 3.)

- LED Brightness Controls (See Figure 1, sheet 2 of 3 and Figure 4, sheet 1 of 3.)

- Firing and Driving Circuitry (See Figure 7.)

- Incremental Modular Optical Encoder Assembly (See Figure 3.)

- Crystal Oscillator, 100 Hz (See Figure 10a.)

- Modified Prism Assembly (See Figure 16, sheet 2 of 3.)

- Power Supply (See Figure 7 and 8.)

Both aft and fore fiducial projector assemblies are part of the optical assembly, AEC which is shown in Figure 4. They are positioned in the vicinity of the focal plane and their optical systems are central with respect to the maximum exposure slit width. Each assembly is equipped with two projectors. The aft fiducial projector assembly contains the center of scan identification mark projector and the aft prism degree mark projector. The fore fiducial projector assembly contains the fore center of scan projector and the timing mark projector. The lens position fiducial projector assembly is mounted directly on the lens cover assembly which is attached to the wobble plate assembly. Since during the IMC stroke the lens position fiducial projector is translated together with the camera lens in the plane parallel to the focal plane, the fiducial mark which is projected and recorded on the film during exposure represents only one specific (calibrated) point mark on the lens. This lens position mark is flashed simultaneously with the prism degree marks every five (5) degrees of the prism rotation which is equivalent to 10° of the photographic scan. Projection and recording of the prism degree, center of scan identification and the timing marks is less complicated and more accurate since all four focal plane projectors are stationary and are located very close to the focal plane.

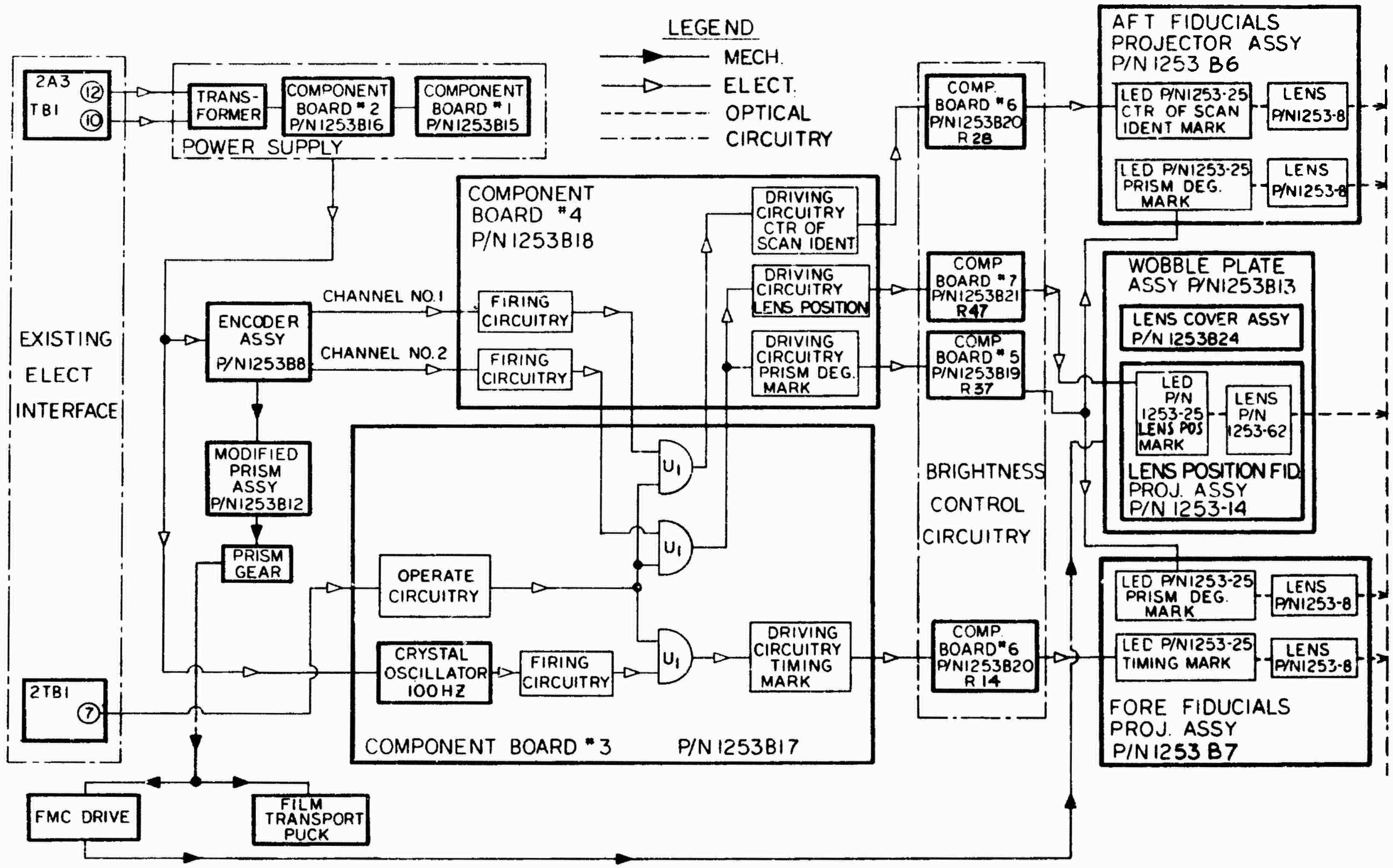


Figure 2. KA-56B Camera Modification Block Diagram

Each of the five projectors contains the following functional components: a solid state light emitting diode (LED), a projection lens and a fixed aperture mask. By means of a lens the LED projects its own light emitting area (0.006 inch dot) directly on the film.

The design provides for separate LED brightness controls R14, R28, R37 and R47 which are located on the following assemblies: R37 on component board #5, R14 and R28 on component board #6 (See Figure 4, sheet 1 of 3.) and R47 on component board #7 (See Figure 1, sheet 2 of 3.). A dual track optical incremental encoder (See Figure 3.) generates all fiducial firing signals with the exception of the timing mark signal which is generated by the 100 Hz crystal oscillator. Since the encoder disc is mounted directly on the extended shaft of the modified prism assembly, this arrangement allows to set the instant of triggering with proper relationship to the angular position of the prism. The outer track (channel #2) of the encoder disc provides a pulse every five (5) degrees of prism rotation. The encoder disc construction is such that pulses are present over two 90° segments which are separated by two blank 90° segments. The 90° rotation of the prism is equivalent to 180° scan angle. The blank segments of the encoder disc represent non-photographic portion of the camera cycle during which the film in the exposure gate remains stationary. The inner track (channel 1) of the encoder disc provides two pulses per one revolution of the prism shaft. Each pulse is positioned approximately at the center of 90° pulse segment of the outer track thus representing the center of scan identification signal.

The signal generated by the outer track is identified as Channel No. 2 signal in the block diagram. This signal is fed into AND gate U_1 whose other input is the OPERATE COMMAND generated in the KA-56B camera. Thus when the camera is in OPERATE the pulse from Channel No. 2 of the encoder is fed into both the prism degree mark drive circuitry and the lens position mark drive circuitry. As shown on the block diagram the output of the prism degree mark circuitry is fed through component board #5 and drives a pair of LED's; one located in the aft fiducial projector assembly and the other in the fore fiducial projector assembly. The output of the lens position mark drive circuitry is fed through component board #7 and drives an LED located in the lens position fiducial projector assembly.

The signal generated by the inner track of the encoder disc is identified as Channel No. 1 signal, in the block diagram. This signal is fed into AND gate U1 whose second input is the OPERATE COMMAND. When an OPERATE COMMAND is present the pulse from Channel No. 2 of the encoder is fed intc the scan identification mark drive circuitry.

The output of the center of scan identification mark circuitry is fed through component board #6 and drives a center of scan identification LED located in the aft fiducial projector assembly.

The timing mark signal is generated by a 100 Hz crystal oscillator located on component board #3. The oscillator output is fed into AND gate U1 whose second input is the OPERATE COMMAND. Thus when the camera is in OPERATE the 100 Hz oscillator signal is fed through the drive circuitry and component board #6 and energizes the timing marker LED, located in the fore fiducial projector assembly.

The following paragraphs provide detailed description of the major purchased components which were utilized in this system.

5.2.1 Optical Encoder

Figure 3 illustrates the optical, modular incremental encoder assembly Model S160 AZ/2-1 (Serial No. 722542) manufactured by the Baldwin Electronics, Inc., Little Rock, Arkansas. The encoder assembly consists of five following major parts: housing, LED amplifier board, dual track timing disc, disc clamp and the dust cover. The dual track is of special design conforming with the modification specification requirements, and it was supplied in a separate package. During the final assembly the LED amplifier board is removed from the encoder housing and the timing disc is secured directly on the prism shaft by means of a disc clamp.

The design characteristics of the encoder are as follows:

a. General Characteristics

(1) Count Track. The encoder provides a count output of 72 CPT. Outputs are present only in the 0° to 90° (19 counts) and 180° to 270° (19 counts) sectors.

(2) Zero Reference Track. A zero reference output is provided on one line at 45° and 225°. The count and reference outputs are not exactly coincident.

(3) Count Track Accuracy. The count track accuracy is ±36 seconds of arc max. pulse to pulse.

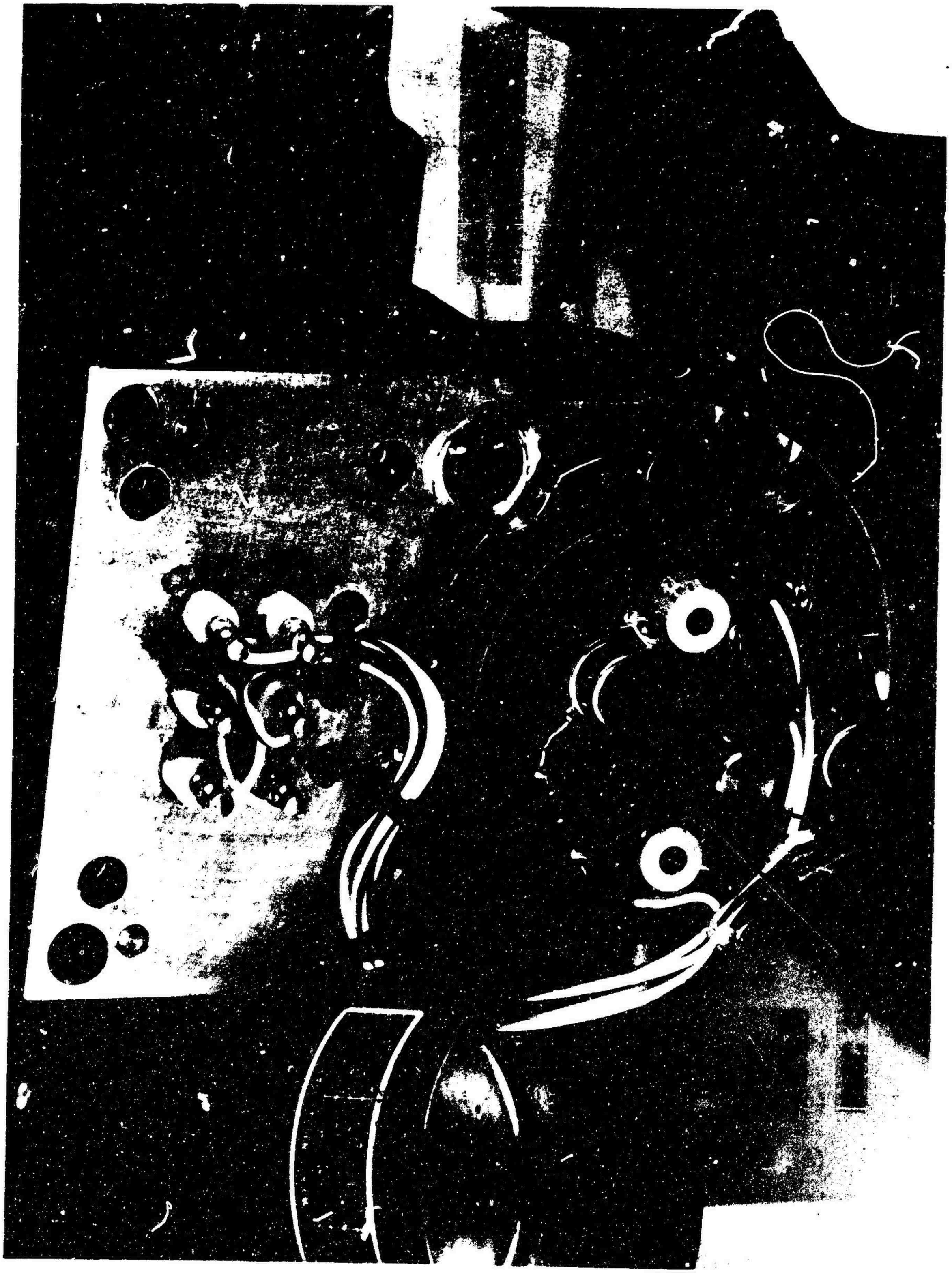


Figure 3. Optical Encoder Assembly

b. Electrical Characteristics

(1) Power Required: +5.0V dc ±5% at 66 ma, max.

(2) Light Source: Solid State Light Emitting Diode (LED)

(3) Frequency Range: 0 to 50 k Hz

(4) Output: High Level: +3.8V dc ±0.5V dc open circuit

Output Impedance: 160 ohms, typical

Low Level: +0.4V dc, max.

Sinking Current: 16 ma, max.

Rise and Fall Time: 200 nanoseconds, max.

(5) F.M. Variation: The period of any cycle shall not deviate more than 0.2% from the nominal length of:

$$\frac{2\pi}{\text{No. of counts per turn}}$$

(6) Bit-to-Bit Error: 0.2% max. (±36 seconds of arc)

c. Mechanical Characteristics

(1) Timing Disc Diameter: 1.250 in.

(2) Disc to Grating Spacing: 0.005 in.

(3) Moment of Inertia: 0.00012 oz-in-sec^2

(4) Prism Shaft Diameter: $0.2498^{+.0000}_{-.0002}$ in.

(5) Shaft Length: 3/4 in. minimum

(6) Shaft Runout: 0.001 in TIR

d. Environmental Requirements

(1) Operating Temperature Range: 0°C to +70°C (+32°F to +158°F)

(2) Storage Temperature Range: -40°C to +85°C (-40°F to +183°F)

(3) Altitude: 70,000 ft.

(4) Vibration: Shall meet and exceed the requirements of Procedure #1 MIL-STD-810B 5 g's max.

(5) Shock: Shall meet or exceed the requirements of MIL-E-5272C and MIL-E-5400K, 15 g's at 11 milliseconds.

(6) Humidity: 95% Rh, avoiding condensation

5.2.2 Crystal Oscillator

Figure 9(a) illustrates the crystal oscillator Model No. CO-231-8 manufactured by Vectron Laboratories, Inc., Norwalk, Connecticut. The design characteristics of the oscillator are as follows:

a. Frequency: 100 Hz

b. Input: 5V dc ±5%

c. Output: TTL/DTL compatible

Fan Out: 10 TTL loads

Logic 0: 0.4V max., sink 16 ma

Logic 1: 2.4V min., source 2 ma

Symmetry: 50/50 ±15%

d. Accuracy: ±0.001% at +25°C (+77°F)

±0.01% over the temperature range of from 0°C to +70°C (32°F to +158°F)

e. Size: 1-1/2" x 1-1/2" x 1/2"

5.2.3 Light Emitting Diode (LED)

Recent technological advances in the development of solid state light emitting diodes have made these items attractive candidates for application in aerial camera systems and specifically in fast moving film, rotary prism panoramic cameras. The use of light emitting diodes as illumination light sources is now feasible and practical. In continuous search for a more reliable miniature data recording device Fairchild Camera and Instrument Corporation has pioneered the development of solid state light emitting sources. Among these are several types of gallium arsenide phosphide diodes which radiate in the optimum region of spectral sensitivity of panchromatic films. A subminiature gallium arsenide phosphide LED lamp FLV107 developed by Fairchild Microwave and Optoelectronics Division, Palo Alto, California, was selected to be utilized in this modification. This state-of-the-art illumination source is very attractive because it features an unusual combination of miniaturization, low cost, ruggedness, light weight, long life and high reliability of solid state component. The FLV107 LED has relatively narrow spectral distribution band with a peak emission wave length of 650 nm, with spectral width between half-power points of 25 nm. The very high transfer-efficiency narrow-band gallium arsenide phosphide LED lends itself to this particular application where optical image transfer of short duration and high brightness is required. Because of the relative motion which exists between projected fiducial image and the moving film in the exposure gate, a short high energy light pulse was required for exposure to avoid an image smear.

The FLV107 is a plastic encapsulated red light emitting diode. It provides an intense, light source with a wide viewing angle. The FLV is the smallest visible lamp available. It has been precision die aligned during manufacture thereby making it highly suitable for positioning in the fiducial projector. The design characteristics of the LED are as follows:

a. Maximum Ratings

(1) Forward DC Current: 35 mA

(2) Peak Forward Current (1 usec pulse 300 pps): 1A

(3) Reverse Voltage: 3 volts

(4) Power Dissipation - Derate 1.0 m W/C° above 25°C: 75 m W

b. Radiant Characteristics at I_F = 20 mA (25°C)

(1) Luminous Intensity: 0.15 mcd min., 0.5 mcd typical

(2) Luminance: 700 mcd/cm^2 typical

(3) Average Emitting Area: 0.75 x 10^{-3} cm^2 typical

(4) Wavelength at Peak Emission: 650 nm

(5) Spectral Width Between Half-Power Points: 25 nm

(6) Rise and Fall Times: 10 ns

c. Electrical Characteristics (25°C)

(1) Forward Voltage at I_F = 20 mA: 1.7V typical, 2V max.

(2) Reverse Breakdown Voltage at I_R = 10 uA: 8.0V typical, 3V min.

d. Environmental Characteristics

(1) Storage Temperature: -55°C to 100°C

(2) Operating Temperature: -55°C to 100°C

(3) Relative Humidity at 65°C: 98%

(4) Solder Temperature for 5 seconds at 0.1 in from seating plane: 260°C

e. Physical Dimensions

$0.090^{\pm 010}$ inch x $0.050^{\pm 007}$ inch x $0.090^{\pm .020}$ inch

5.3 CAMERA BODY MODIFICATION.

The following paragraphs contain a detailed discussion of the modifications implemented on the following major camera body assemblies:

- Optical Assembly AEC (See Figure 3).
- Wobble Plate Assembly (See Figure 1, sheet 2 of 3).
- Prism Assembly (See Figure 16, sheet 3 of 4).
- Cover Assembly (See Figure 7).
- Camera Housing.

Discussion of each modification will include the description of the design changes made to the existing equipment and the description of the new implemented flash fiducial system components developed by Fairchild.

5.3.1 Optical Assembly, AEC

The modified optical assembly AEC is shown in Figure 4. Due to design changes requiring machining operations to be performed on the shutter and the mounting plate itself, the assembly was disassembled completely.

In order to provide sufficient space necessary for the accommodation of the new focal plane flash fiducial projectors and to provide an ample operational clearance for the translating lens position fiducial projector some of the existing parts were removed and obsoleted, some were redesigned and replaced with the new parts of similar design and some parts were reworked.

The shield, lens assembly P/N 1076B121, screw machine optical assembly P/N 1076-1071 and plate P/N 1076-1209 were removed from the assembly and obsoleted. The mirror and the plate holding mirror were redesigned and replaced with new parts of similar design. Thickness of the mirror was reduced to approximately 0.070 inch and thickness of the plate holding mirror to 0.020 inch. A milling operation was performed on the AEC mounting plate, to provide a new seating surface for the plate holding mirror and the necessary cavity for the data recording harness which was rerouted from its previous position, twenty-six (26) new

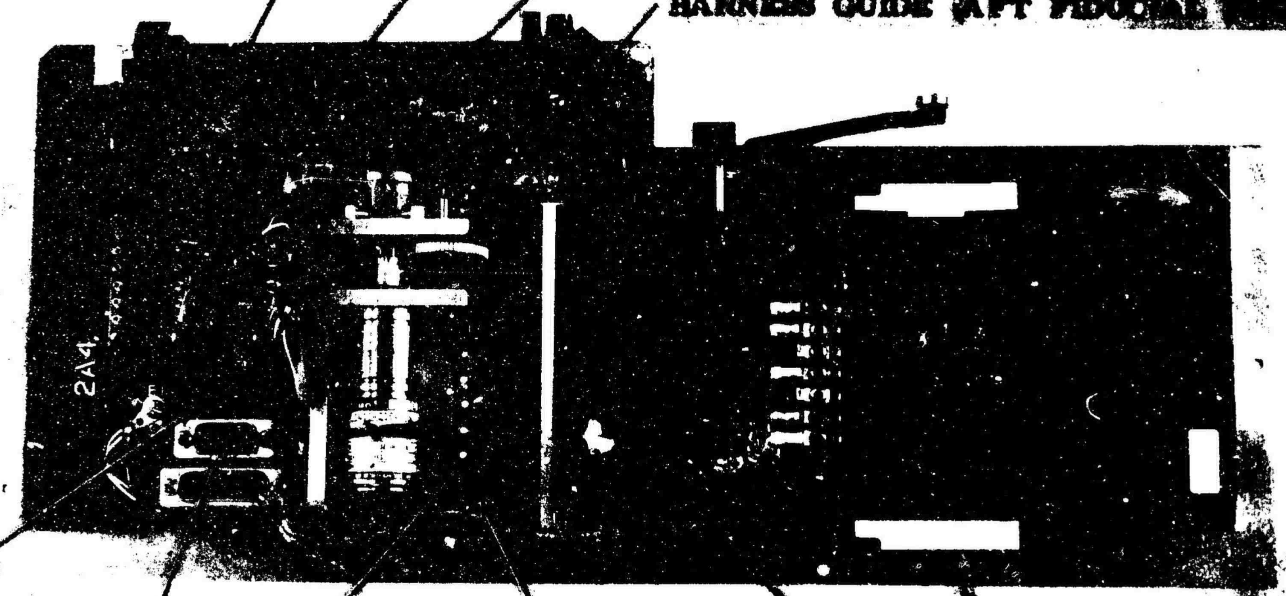


Figure 4. Optical Assembly, AEC (Sheet 1 of 3)

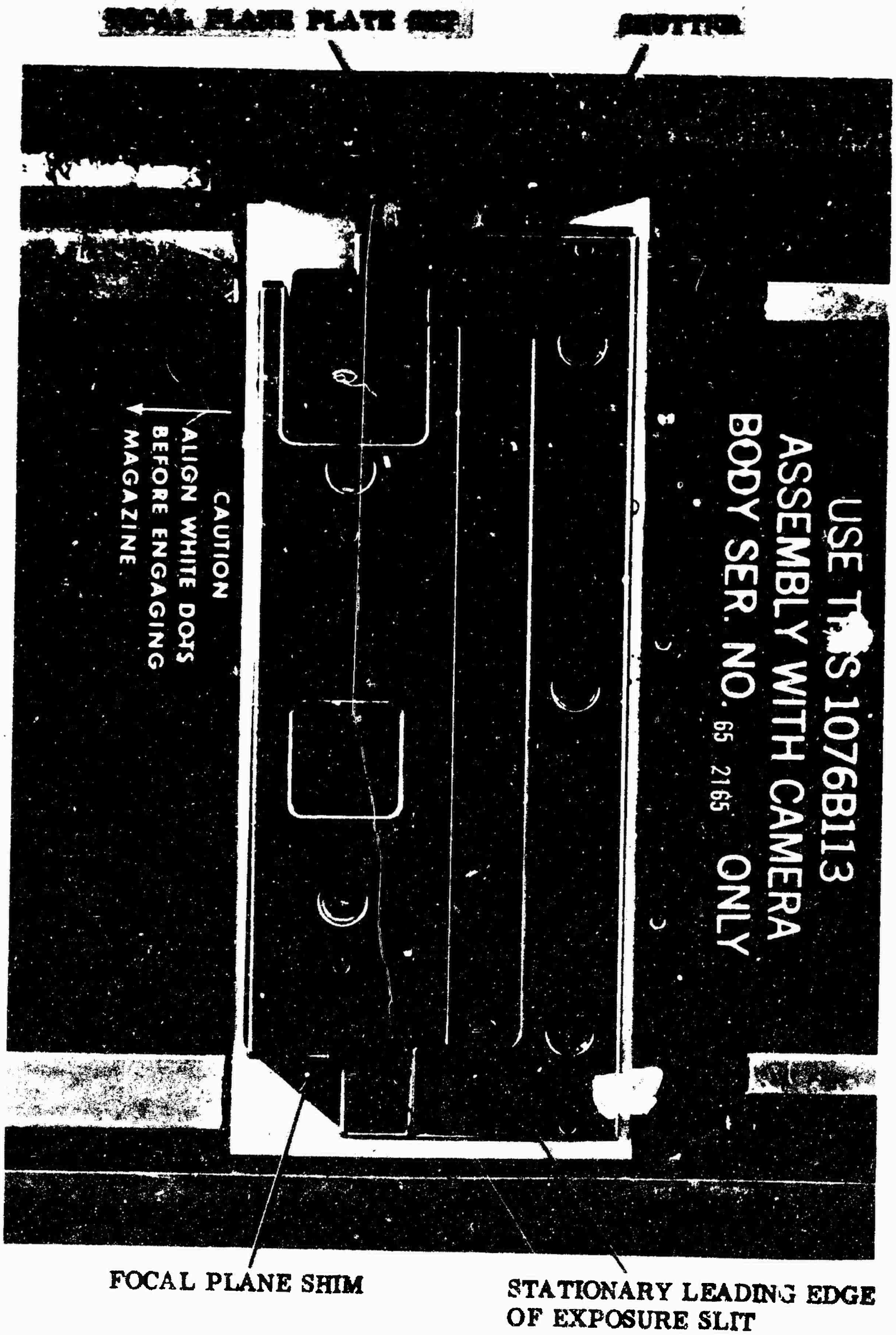


Figure 4. Optical Assembly, AEC (Sheet 2 of 3)

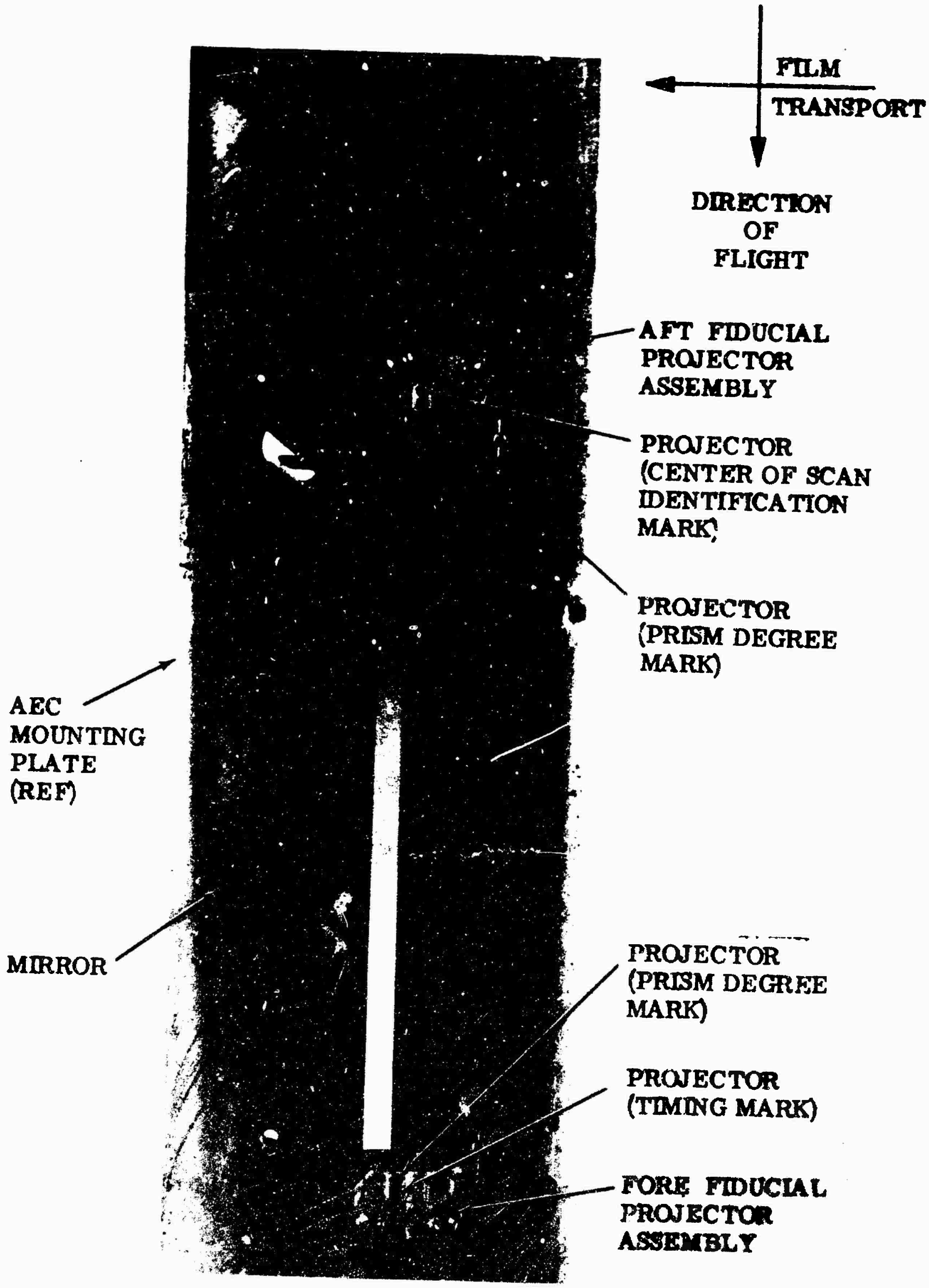


Figure 4. Optical Assembly, AEC (Sheet 3 of 3)

holes were drilled and tapped,and the film guides were refinished. The existing set of the focal plane plates was obsoleted and replaced with the new one of simiiar design. The existing set could not be reworked since the rework would require addition of the material. A small milling operation was performed on both ends of the shutter blade and the focal plane shim, to provide a sufficient clearance for the focal plane fiducial projectors.

The following major new parts, controls and subassemblies which are identified in Figure 4 were added as a result of the modification:

a. Connector

A new connector was added to interface focal plane flash fiducial circuitry located on the optical assembly, AEC with the firing and driving circuitry which is located in the cover assembly (See Figure 7).

b. Connector Bracket

c. Plate, Holding Mirror

d. Mirror

e. Harness Guide (Fore Fiducial Projector)

f. Harness Guide (Aft Fiducial Projector)

g. Terminal Board Assembly

h. Component Board #5

Component Board #5 contains resistor R37, which controls the brightness of the prism degree LED's.

i. Component Board #6

The component board contains resistors R14 and R28 controlling the brightness of the timing, and center of scan LED's respectively.

j. Focal Plane Plate Set

The new focal plane set includes the following design changes:

(1) Two cavities were added on the back side of the plate to accommodate the front portion of the aft and fore fiducial projector assemblies (See Figure 5, P/N 1253-9).

(2) Four (4) 0.031 inch diameter clearance holes were added to clear the path for the projected light bundle of the focal plane fiducial projectors.

(3) The exposure slit length was decreased to 4.188 inch to conform with the new design requirements which were discussed previously.

(4) The cross sectional geometry of the leading edge of the exposure slit was changed to provide a clear path for the projected light bundle of the lens position fiducial projector (see Figure 6, P/N 1253-3).

k. <u>Fore and Aft Fiducial Projector Assemblies</u>

Since both projector assemblies are of similar design, only the aft projector assembly will be discussed. The focal plane fiducial projector assembly is illustrated in Figure 5.

The projector assembly consists of a stainless steel body which houses two subminiature state-of-the-art fiducial projectors. Each projector consists of one modified gallium arsenide phosphide LED lamp FLV107, one spherical lens element and one lens retaining mask. The LED lamp FLV107 was modified by FSDS to suit the optical design requirements of the system.

The optical system utilizes a precision ground and polished 0.0468 ±0.0001 in. dia. sphere of clear synthetic sapphire to project the 0.006 inch diameter light emitting area of the LED at an approximate magnification of 1.5:1 to a 0.010 inch diameter dot on the film emulsion. A sphere lens design was used, because of its large characteristic spherical aberration. This property is utilized in the design to provide the large depth of focus, since the film is not vacuum held in the exposure gate. Due to a narrow spectral bandwidth of the GaAsP LED chromatic

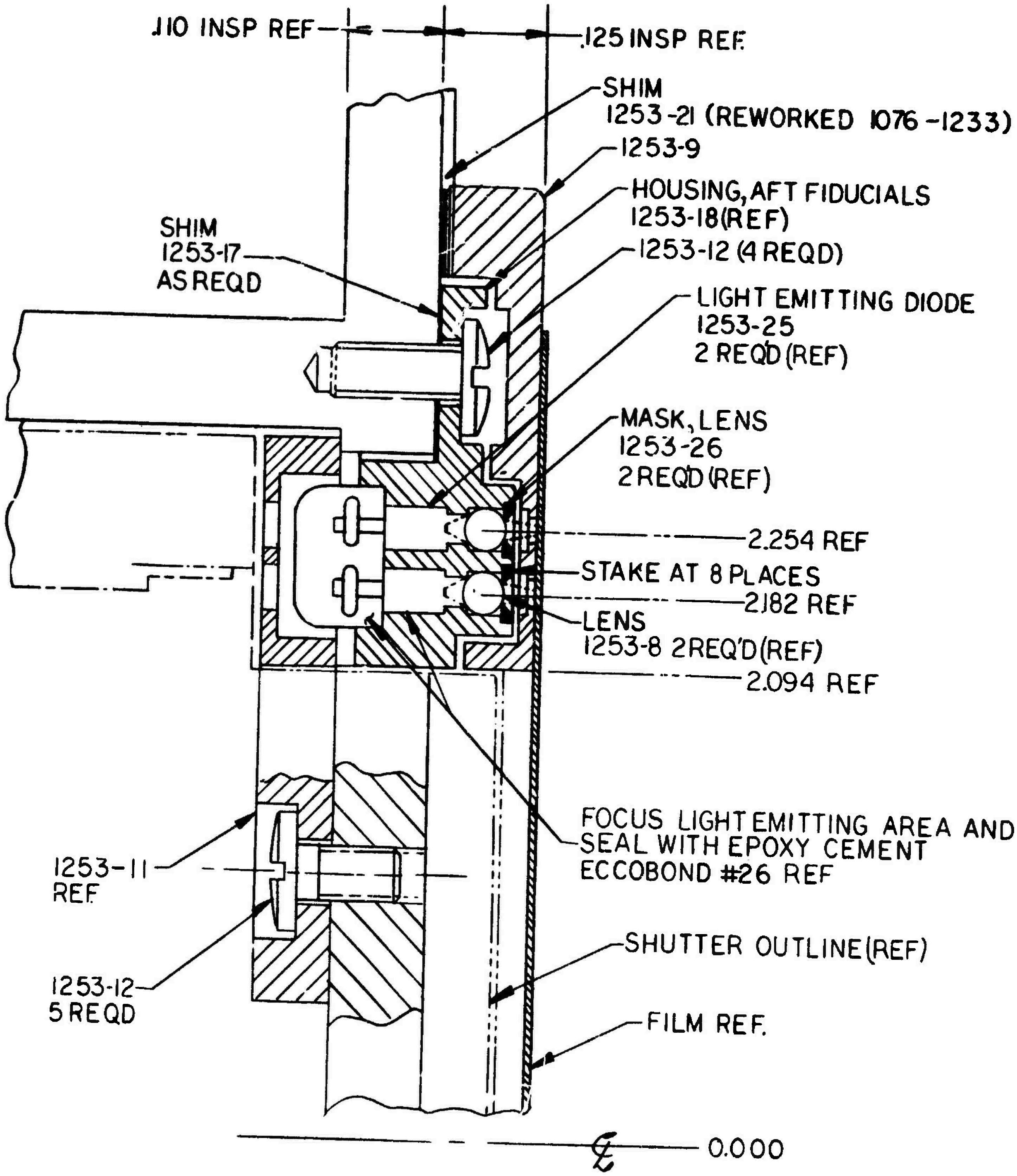


Figure 5. Typical Focal Plane Fiducial Projector Assembly

aberration does not have to be corrected thus allowing a simple single element design. The assembly was par-focalized so that the projected image of the LED light emitting area is focused at a precise distance from the seating flange. This method of assembly ensures the accurate focus of the image on the focal plane. After the focusing operation was completed the LED, and its four soldered wire joints were encapsulated with Eccobond #26 epoxy cement. The small gage wiring from projectors, terminates at the terminal board assembly. Specially designed harness guides are used to guide and clamp all wires to insure that they will not interfere with the operation of the shutter mechanism.

At the final assembly, both fore and aft fiducial projectors were adjusted for parallelism in respect to the leading edge of the exposure slit within ±0.001 inch accuracy. Normally fiducial projectors would be doweled to maintain their setting, however, past experience has proven that proper accuracy cannot be held during the drilling and reaming operation for the dowel pin. A layer of glyptal #1276 was applied around the projector flange, and on top of the mounting screw heads to prevent any shift from their set positions.

The novel state-of-the-art subminiature focal plane fiducial projector design proved to be compact, reliable and rugged. It provided sharp, dense, high quality images.

5.3.2 Wobble Plate Assembly

In order to accomplish the necessary modifications on the wobble plate assembly, the camera body assembly had to be taken apart and the entire package consisting of the wobble plate assembly and the camera lens was partially disassembled. The following major assemblies were added to the existing wobble plate assembly:

a. Lens Cover Assembly

The lens cover assembly (see Figure 1, sheet 2 of 3) consists of black anodized aluminum flanged cylindrical body, four insulated terminals and small electrical harness secured to the lens cover by means of five modified miniature commercial clamps. The

assembly is placed over the rear end of the camera lens barrel and secured to the lens barrel support of the wobble plate assembly by means of four special screws.

b. <u>Lens Position Fiducial Projector Assembly</u>

The lens position fiducial projector assembly (see Figure 6) consists of the following components: base, LED housing, modified FLV107 LED, lens housing, lens, two (2) set screws and the electrical wiring connecting LED to the insulated terminal located on the lens cover assembly.

The optical system utilizes a simple 8 millimeter focal length, f/4.0 biconvex lens to project the lens position fiducial dot at an approximate magnification of 1.3:1. Single element design was possible due to the narrow spectral bandwidth of the LED. The LED lamp used was a modified version of FLV107. The modification was very minor and not affecting the performance characteristics of the LED; the standard hemispherical LED lens was substituted with flat layer of clear epoxy to suit the optical design requirements of the projection system. The LED and its two soldered wire joints were encapsulated with Eccoband #26 epoxy cement. The assembly was parfocalized so that the projected image on the LED light emitting area is focused at the precise distance from the mounting surface of the base.

Final critical adjustments were made during the final assembly. The optical axis of the projector was adjusted laterally in respect to the stationary leading edge of the exposure slit, so that the fiducial dot image was produced as close as possible to the leading edge of the exposure slit. This adjustment was performed at the minimum slit width in order to insure that at the minimum slit width the projected light bundle will not be obstructed by both the leading and the trailing edge of the exposure slit. Several operational photographic tests were performed at the cycling rate of 1 cps and each time the geometry of the dot was evaluated and gradual adjustments were made until the full image of the dot was recorded on the film. A layer of glyptal #1276 was applied around the projector base, and on top of the mounting

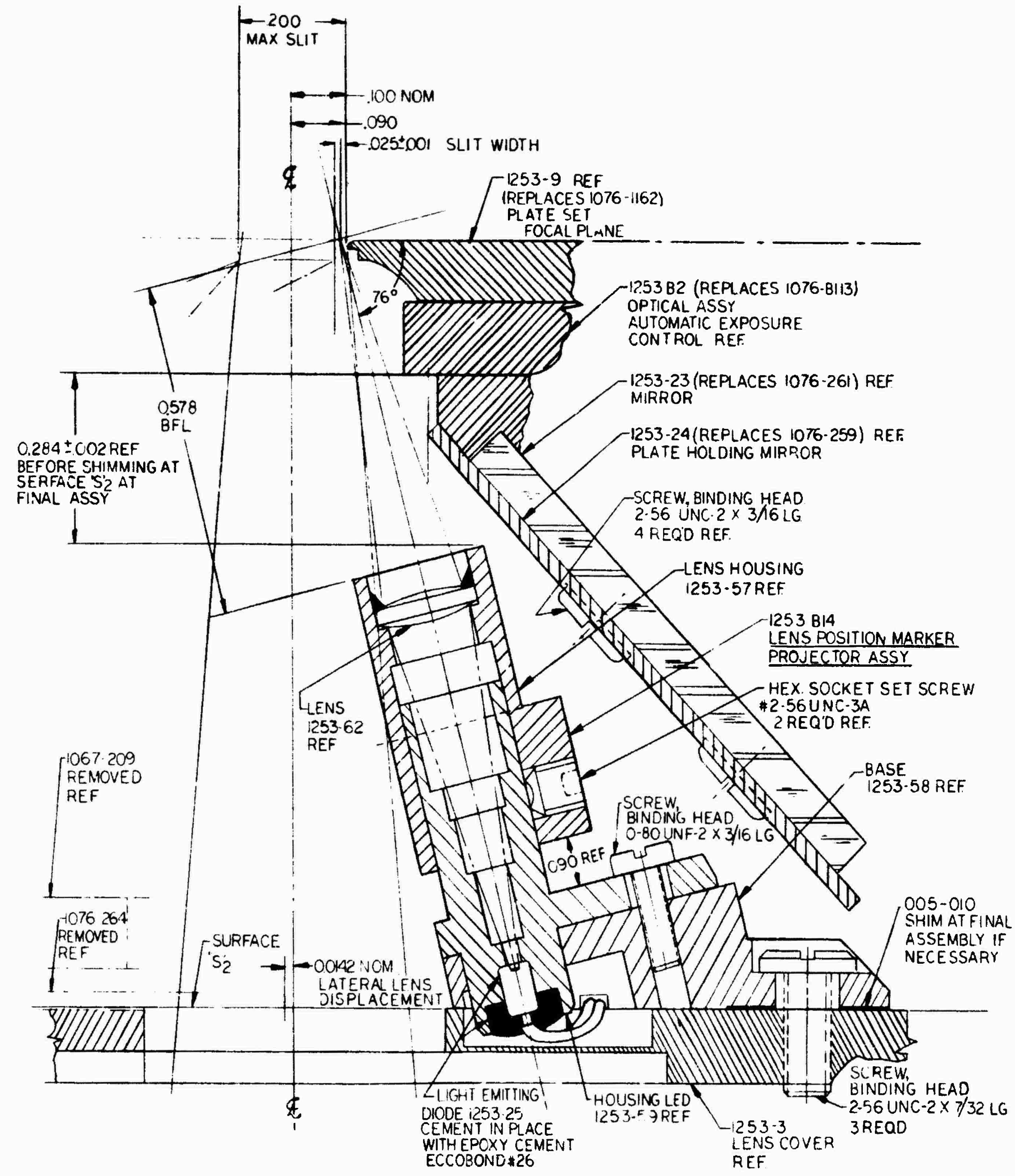


Figure 6. Lens Position Fiducial Projector Assembly

screw heads to ensure that the projector assembly will not move from its set position.

c. Flexible Conductor Assembly

During the camera operation electrical continuity must be maintained between the stationary component board #7 assembly and the translating lens position fiducial projector assembly. Standard connection method utilizing short insulated wire loops soldered to terminals could not be used since the repeated stresses resulting from the oscillating motion of the lens during IMC translation would cause an early fatigue failure at the soldered joints and possible damage to the conductor's insulation. Long free loops utilizing standard insulated wire could not be used as well since their position cannot be predicted during the acceleration or deceleration of the aircraft. Thus a new fatigue proof method of connection providing for controlled displacement of the conductors was developed.

The developed flexible conductor assembly (see Figure 1, sheet 2 of 3) consists of two terminal board assemblies and two gold plated and heat treated flat beryllium copper springs. One terminal board assembly is mounted on the translating lens cover assembly, while the other is secured to the stationary gimbal support of the wobble plate assembly. Each end of the typical flexible conductor spring is secured to its respective terminal bracket by means of a clamping plate, a solder type wire terminal and the mounting screw. From there on standard wiring methods are used.

d. Component Board #7 Assembly

The component board #7 assembly contains resistor R47, which controls brightness of the lens position LED. This assembly is attached to the terminal board assembly by means of four screws.

e. Modified Counterweight Assembly

The modified counterweight assembly is shown in Figure 1, sheet 3 of 3. An additional weight was added to the existing counterweight assembly in order to compensate

the weight of the added modifications located on the camera lens. The static balancing of the lens-wobble plate assembly will be covered in Section VI, paragraph 6.6.

5.3.3 Prism Assembly

In order to insure the accuracy of the flash fiducial firing system, the encoder timing disc had to be mounted directly on the prism shaft. Since the existing shaft was not long enough to reach the encoder level, a new extended shaft was electron-beam welded to satisfy new design requirements.

The prism assembly (former P/N 1076B27) was reassembled and aligned with the bearing axis with the best possible accuracy. The inspection results revealed that the axis of the prism P/N 1076B7 was concentric with the bearing axis within 0.0008 in TIR, and both axes were parallel within 0.0004 inch. These accuracies are approximately 1,200% better than the standard acceptable accuracies listed in the prism assembly Drawing No. 1076B27.

5.3.4 Cover Assembly

The cover assembly (see Figure 7) contains the following major assemblies and components:

- Component Board #1 Assembly (see Figure 8)
- Component Board #2 Assembly (see Figure 8)
- Transformer (see Figure 7)
- Component Board #3 Assembly (see Figure 9)
- Component Board #4 Assembly (see Figure 10)
- Adapter Plate Assembly (see Figure 3)
- Cover
- Connector
- Connector Bracket

The power supply section consists of the component board #1 assembly, component board #2 assembly and transformer.

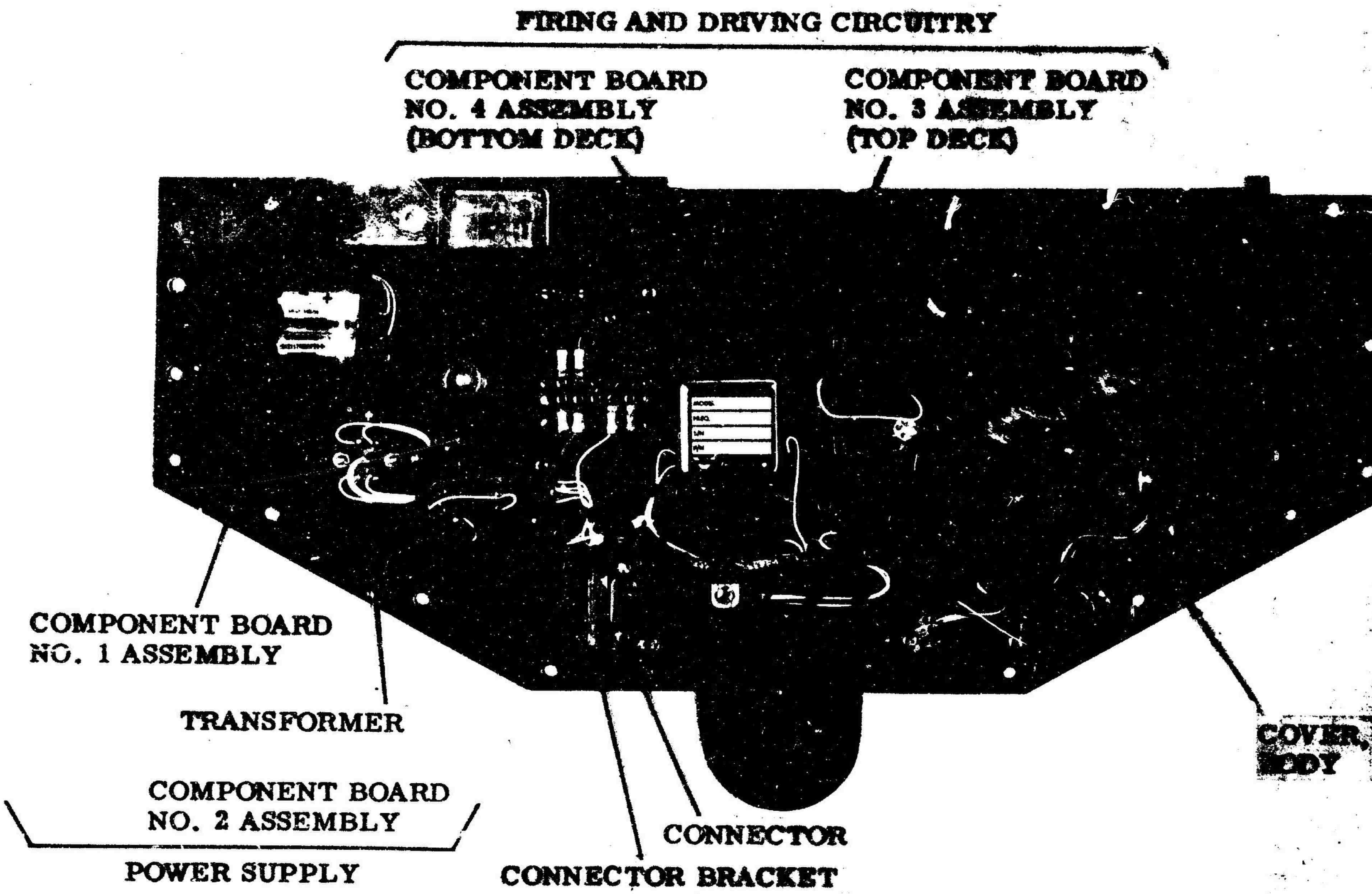
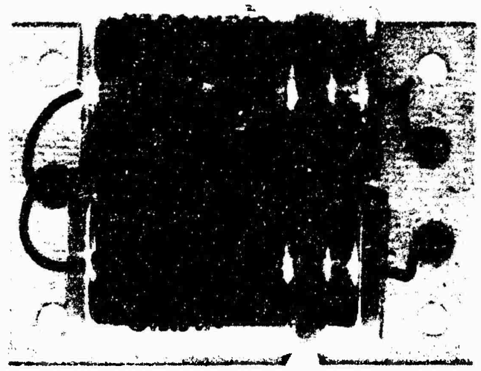
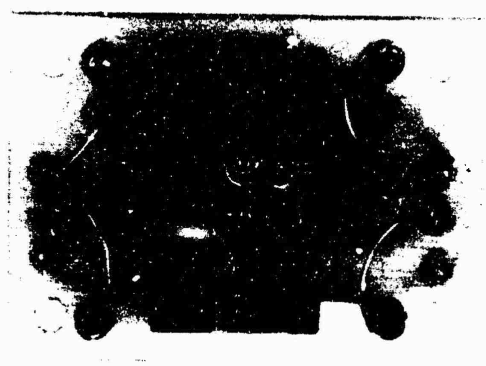


Figure 7. Cover Assembly



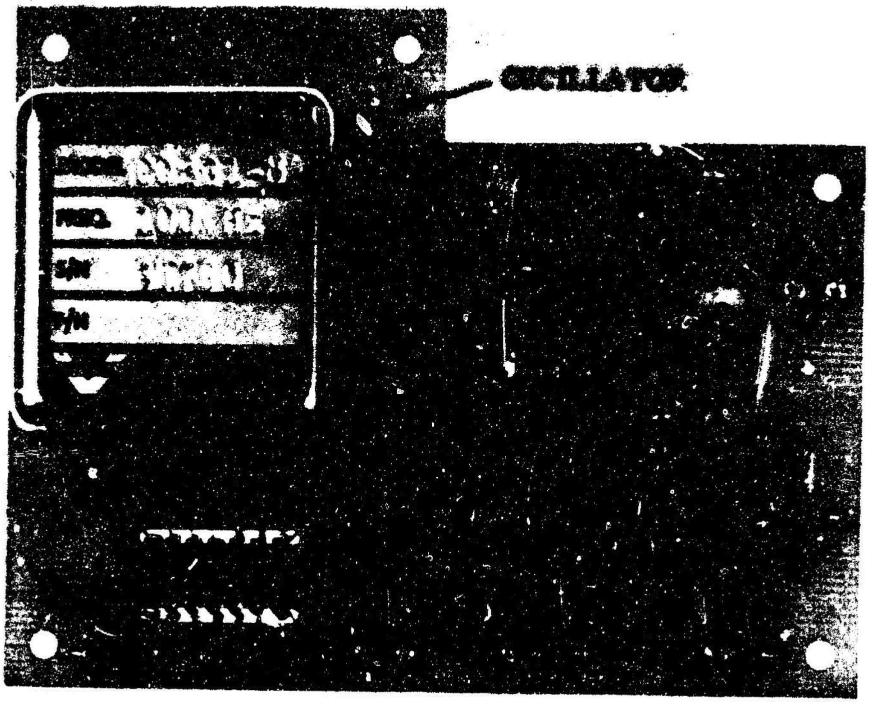
(a) COMPONENT BOARD #1 ASSEMBLY

(b) COMPONENT BOARD #2 ASSEMBLY
(NEAR SIDE)

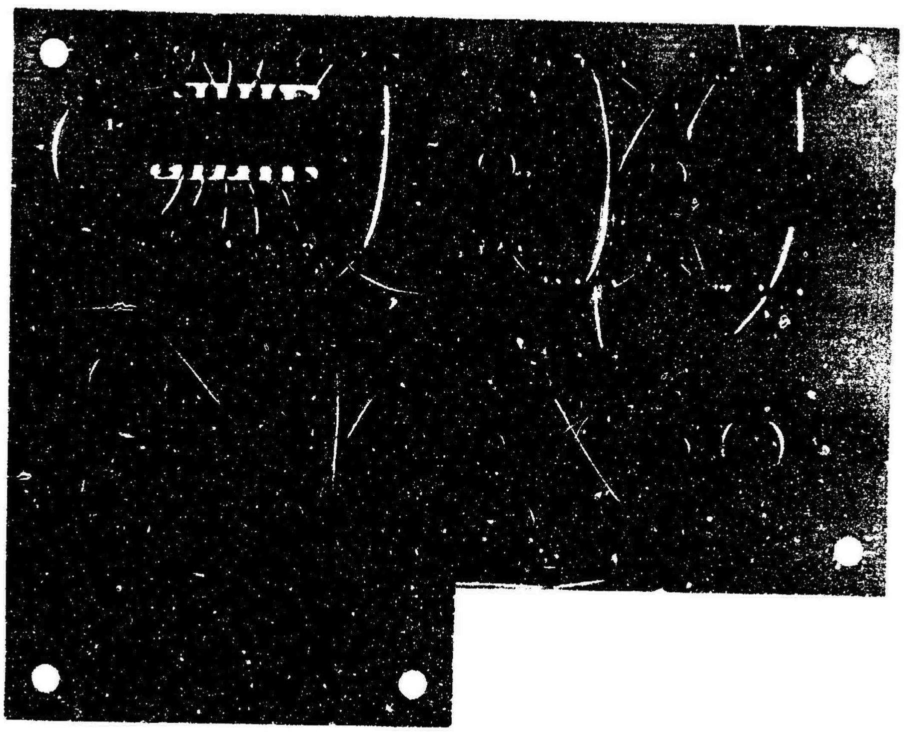


(c) COMPONENT BOARD #2 ASSEMBLY
(FAR SIDE)

Figure 8. Power Supply Components

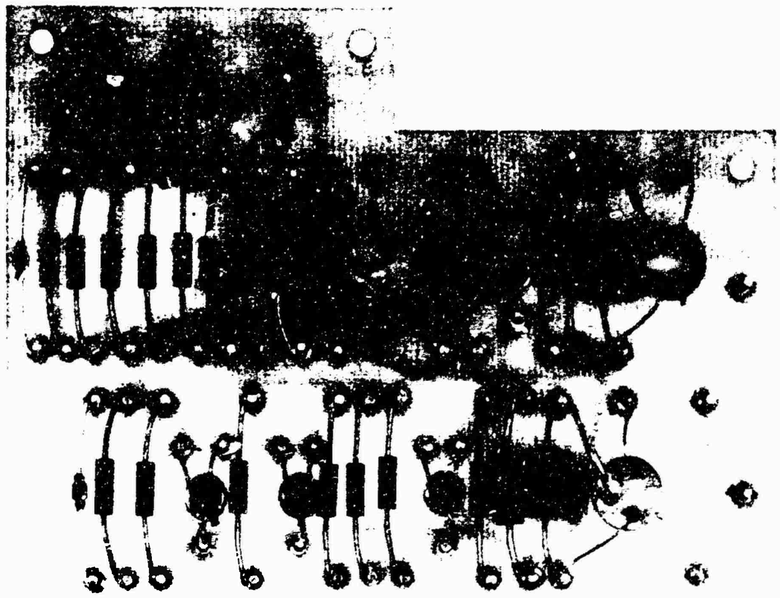


(a) NEAR SIDE

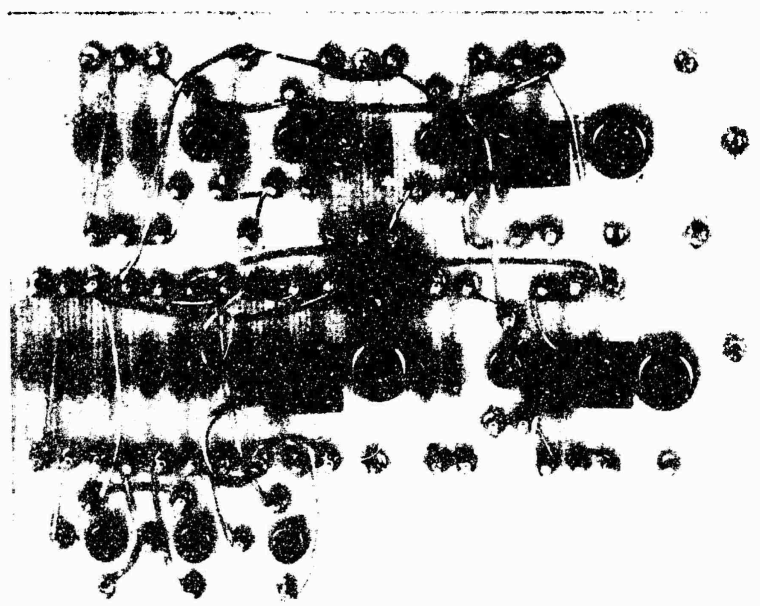


(b) FAR SIDE

Figure 9. Component Board #3 Assembly (Top Deck)



(a) NEAR SIDE



(b) FAR SIDE

Figure 10. Component Board #4 Assembly (Bottom Deck)

The firing and driving circuitry package consists of the component board #3 and #4 assemblies. Component board #3 contains a 100Hz crystal oscillator which was described in paragraph 5.2.2. A detailed functional description of the power supply and the firing and driving circuitry will be given in paragraph 5.3.6 titled "Electrical Schematic".

The following assemblies and components were removed from the cover assembly and obsoleted for this modification:

- Cover Access Photocell P/N 1076-84
- Gasket P/N 1076-83
- Harness Assembly P/N 1076B109
- Aperture Lampholder P/N 1076-812
- Lampholder P/N 1076-935

The obsolete parts are replaced by the adapter plate assembly and the prism degree and center of scan identification fiducial projectors.

5.3.5 Camera Housing

The following miscellaneous parts, mounted directly on the camera housing were added to the camera body assembly; bracket and connector interfacing optical assembly AEC, bracket and connector interfacing cover assembly (see Figure 1, sheet 2 of 3), and adapter cover (see Figure 1, sheet 1 of 3).

A very minor rework consisting of drilling and counterboring operations was performed on the camera housing to provide mounting facilities for the connector bracket interfacing cover assembly.

The existing mounting plate (see Figure 1, sheet 3 of 3) was modified to provide the required space for the modified counterweight assembly.

5.3.6 Electrical Schematic

The overall detailed schematic of the system is shown in Figure 11.

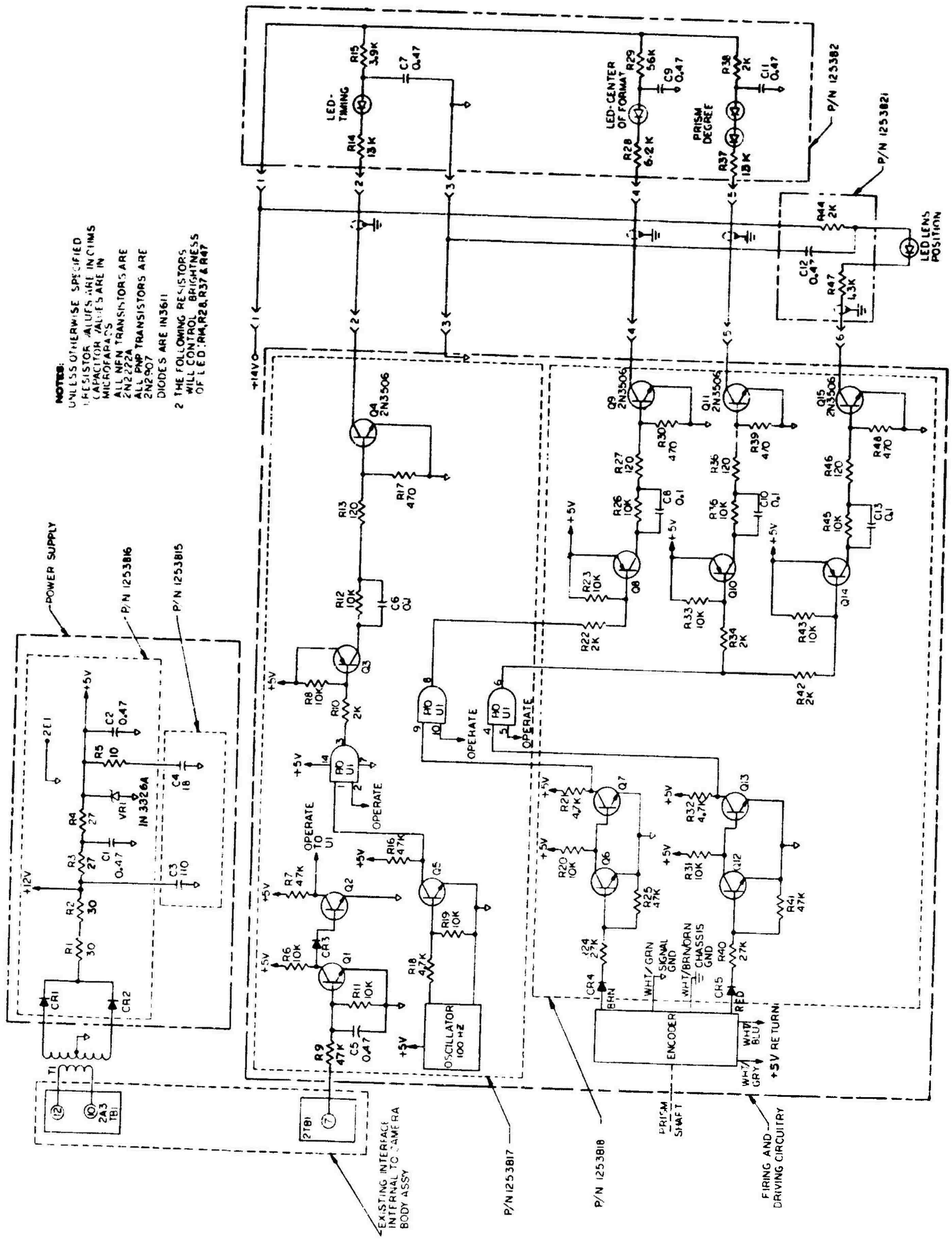


Figure 11. Electrical Schematic (Sheet 1 of 4)

SCHEMATIC PARTS LIST					
REF. DESIGNATION	DESCRIPTION	VALUE	TOL.	RATING	PART NUMBER
R1	RESISTOR	30	±5%	1/2W	RC20G030JM
R2		30		1/2W	RC20G030JM
R3		27		2W	RCR42G270JM
R4		27		2W	RCR42G270JM
R5		10		1W	RCR32G100JM
R6		10K		1/4W	RCR07G103JM
R7		4.7K			RCR07G472JM
R8		10K			RCR07G103JM
R9		47K			RCR07G473JM
R10		2K			RCR07G202JM
R11		10K			RCR07G103JM
R12		10K		1/4W	RCR07G103JM
R13		120		1/2W	RCR20G120JM
R14		13K		1/2W	RC20GF133J
R15		3.9K		1/2W	RC20GF392J
R16		4.7K		1/4W	RCR07G472JM
R17		470			RCR07G470JM
R18		4.7K			RCR07G472JM
R19		10K			RCR07G103JM
R20		10K			RCR07G103JM
R21		4.7K			RCR07G472JM
R22		2K			RCR07G202JM
R23		10K			RCR07G103JM
R24		27K			RCR07G273JM
R25		47K			RCR07G473JM
R26		10K		1/4W	RCR07G103JM
R27		120		1/2W	RCR20G120JM
R28		6.2		1/2W	RC20GF622J
R29		56K		1/2W	RC20GF563J
R30		470		1/4W	RCR07G470JM
R31	RESISTOR	10K	±5%	1/4W	RCR07G103JM

FIGURE 11 ELECTRICAL SCHEMATIC (SHEET 2 of 4)

SCHEMATIC PARTS LIST					
REF. DESIGNATION	DESCRIPTION	VALUE	TOL.	RATING	PART NUMBER
R32	RESISTOR	4.7K	±5%	1/4W	RCR07G472JM
R33		10K			RCR07G103JM
R34		2K			RCR07G202JM
R35		10K		1/4W	RCR07G103JM
R36		120		1/2W	RCR20G120JM
R37		13K		1/2W	RC20GF133J
R38		2K		1/2W	RC20GF202J
R39		470		1/4W	RCR07G470JM
R40		27K			RCR07G273JM
R41		47K			RCR07G473JM
R42		2K			RCR07G202JM
R43		10K		1/4W	RCR07G103JM
R44		2K		1/2W	RC20GF202J
R45		10K		1/4W	RCR07G103JM
R46		120		1/2W	RCR20G120JM
R47		1.3K		1/2W	RC20GF132J
R48	RESISTOR	470	±5%	1/4W	RCR07G470JM
	INTEGRATED CIRCUIT				U6A994651X Fairchild Semi-conductor
CR1	DIODE				1N3611
CR2					
CR3					
CR4					
CR5	DIODE				1N3611
VR1	DIODE, ZENER				1N3826A
	OSCILLATOR	100 Hz			Type CO231-8 Vectron Lab.

FIGURE 11 ELECTRICAL SCHEMATIC (SHEET 3 of 4)

SCHEMATIC PARTS LIST					
REF. DESIGNATION	DESCRIPTION	VALUE	TOL.	RATING	PART NUMBER
Q1	TRANSISTOR				2N2222A
Q2					2N2222A
Q3					2N2907
Q4					2N3506
Q5					2N2222A
Q6					2N2222A
Q7					2N2222A
Q8					2N2907
Q9					2N3506
Q10					2N2907
Q11					2N3506
Q12					2N2222A
Q13					2N2222A
Q14					2N2907
Q15	TRANSISTOR				2N3506
C1	CAPACITOR	0.47 μf	±10%	75V	CK06BX474M
C2		0.47 μf	±10%	75V	CK06BX474M
C3		110 μf	-10 +75%	50V	601D117G050FE4
C4		18 μf	-10 +50%	50V	601D186F150FE4
C5		0.47 μf	±10%	75V	CK06BX474M
C6		0.1 μf			CK06BX104K
C7		0.47 μf			CK06BX474M
C8		0.1 μf			CK06BX104K
C9		0.47 μf			CK06BX474M
C10		0.1 μf			CK06BX104K
C11		0.47 μf			CK06BX474M
C12		0.47 μf			CK06BX474M
C13	CAPACITOR	0.1 μf	±10%	75V	CK06BX104K

FIGURE 11 ELECTRICAL SCHEMATIC (SHEET 4 of 4)

a. Interface

There are four points where the modification circuitry is interfaced with the existing KA-56B system. Terminals 2A3-12 and 2A3-10 provide the 115,400 Hz power, terminal 2TB-7 provides the camera OPERATE COMMAND and terminal 2E1 connects the modification electronics "ground" to the existing KA-56B system ground.

b. Power Supply

Transformer T1 feeds a full wave rectifier which produces the +12V dc supply for the LED firing circuits. Zener diode VR1 generates the +5V dc power required by the oscillator, optical encoder and logic circuitry. Transformer T1 also isolates the modification electronics return from the KA-56B ground. The modification electronics return is referenced to the center tap on T1 which is connected at one point to the KA-56B ground (2E1).

c. Conditioning Circuitry

Transistors Q1, Q2, Q5, Q6, Q7, Q12, and Q13 condition the operate, oscillator and encoder signals to be compatible with gate U1.

d. Firing and Driving Circuitry

The configurations of the firing circuits are identical for all LED's, the only difference being the magnitude of the current through the LED. The following description applies to the timing mark firing circuit.

When pin 3 of U1 goes to ground transistor Q3 conducts providing base current for Q4, which permits current to flow through the timing LED. Capacitor C6 provides a short circuit around R12 which provides sufficient current into the base of Q4 to turn Q4 ON. However, after C6 charges up, R12 is in the circuit and since it is much larger than R13 and R17 there is insufficient Q4 base current (and base-emitter voltage) to keep Q4 ON. Therefore, the duration of the current pulse through the LED is determined by the R12 - C6 time

constant, the magnitude of R13 and R17 and the characteristics of Q4. The magnitude of the current through the LED is determined by the value of R14. C7 charges to +14V when Q4 is OFF. When Q4 goes ON, C7 discharges through the LED, R13 and Q4. Therefore, the magnitude of the current through the LED is controlled by the value of the resistor in series with the LED and the drive transistor, Q4.

e. <u>Led Brightness Control</u>

By varying the value of the resistor R14, the brightness of the LED can be adjusted in order to achieve proper exposure characteristics of the fiducial mark.

5.4 EXPOSED FILM FORMAT.

The following fiducial marks are identified on the exposed film format diagram shown in Figure 12, Sheet 1 of 2.

- Center of scan identification mark
- Prism degree fiducial marks
- Timing fiducial mark
- Lens position fiducial mark

The actual full size reproduction is shown in Figure 12, sheet 2 of 2.

a. <u>Center of Scan Identification Mark</u>

The center of scan identification mark is located on the aft side of the format and is slightly offset from the 90° prism degree fiducial mark, which indicates the true center of the scan (nadir position of the prism). The size of the identification mark and the accuracy of the recording are not critical since this mark is used for identification purposes only.

b. <u>Prism Degree Fiducial Marks</u>

The prism degree fiducial marks are exposed along the fore and aft edge of the format. They are flashed every 5° of prism rotation with the accuracy of ±36 seconds of

arc, and recorded on the film every 10° of the panoramic scan, with the accuracy of ±72 seconds of arc. The total maximum accumulative error over entire 180° scan does not exceed ±72 seconds of arc. Nineteen (19) fiducial marks are recorded on each side of the format covering full 180° panoramic scan.

The nominal distance between two 10° prism marks is derived from the following relationships:

$$D_p = \frac{\text{Film Format Length}}{180^{\circ} / 10^{\circ}}$$

$$= \frac{\pi \times EFL}{18}$$

$$= \frac{\pi \times R}{18}$$

where: D_p = Nominal distance between two 10° prism marks (in)

π = Scan angle (radians)

EFL = Effective focal length (in)

R = Film transport puck radius (in)

= 2.943 in.

substituting values in the above equation, we have:

$$D_p = \frac{3.14159 \times 2.943}{18}$$

$$= 0.5136 \text{ inch}$$

The "design goal accuracy" of ±30 seconds of arc (±0.00043 in) was not achieved due to limited accuracy of the small diameter encoder disc (larger and more accurate encoder could not be used in the small space envelope available for the mounting of the encoder assembly).

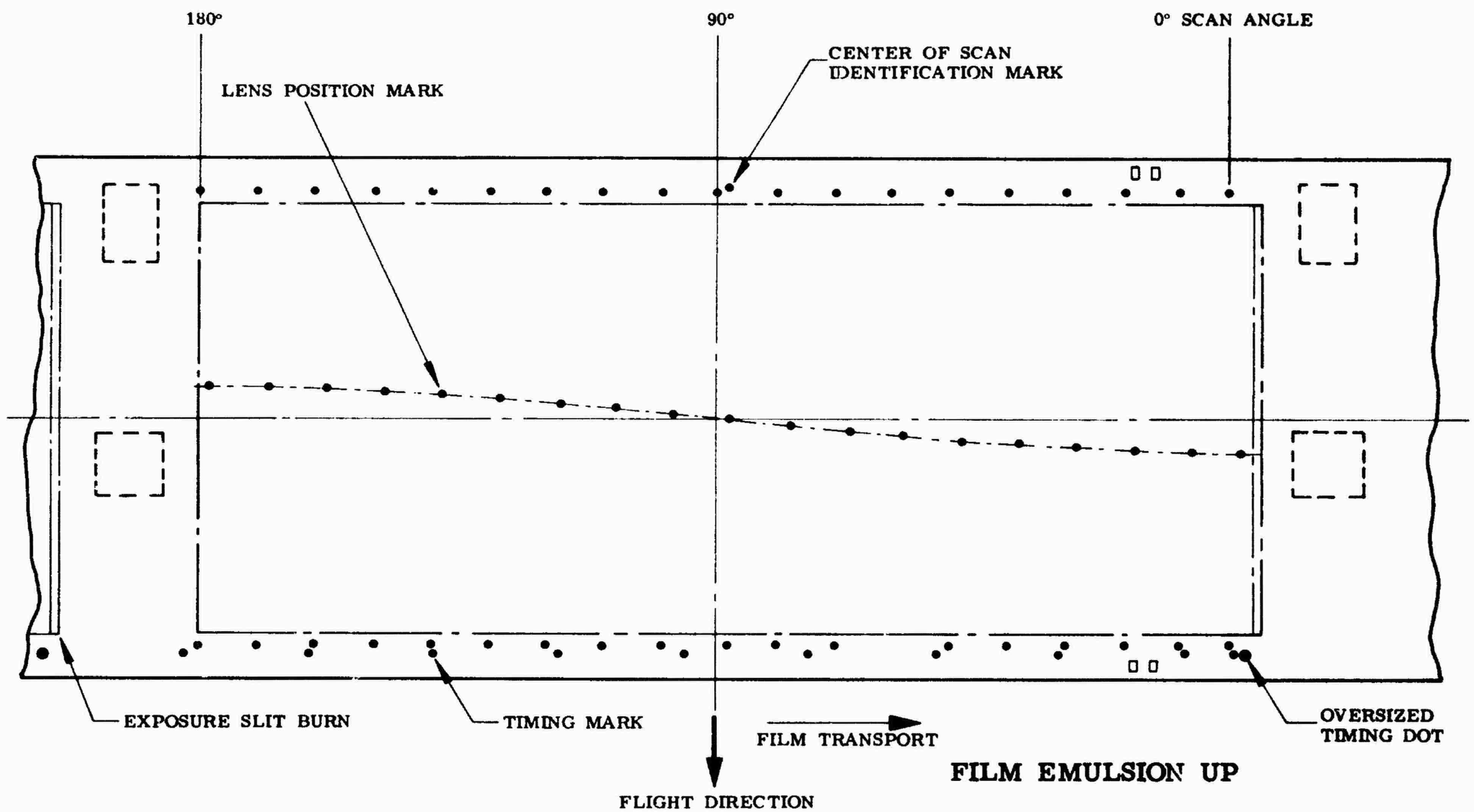


FIGURE 12. FILM FORMAT (SHEET 1 of 2)

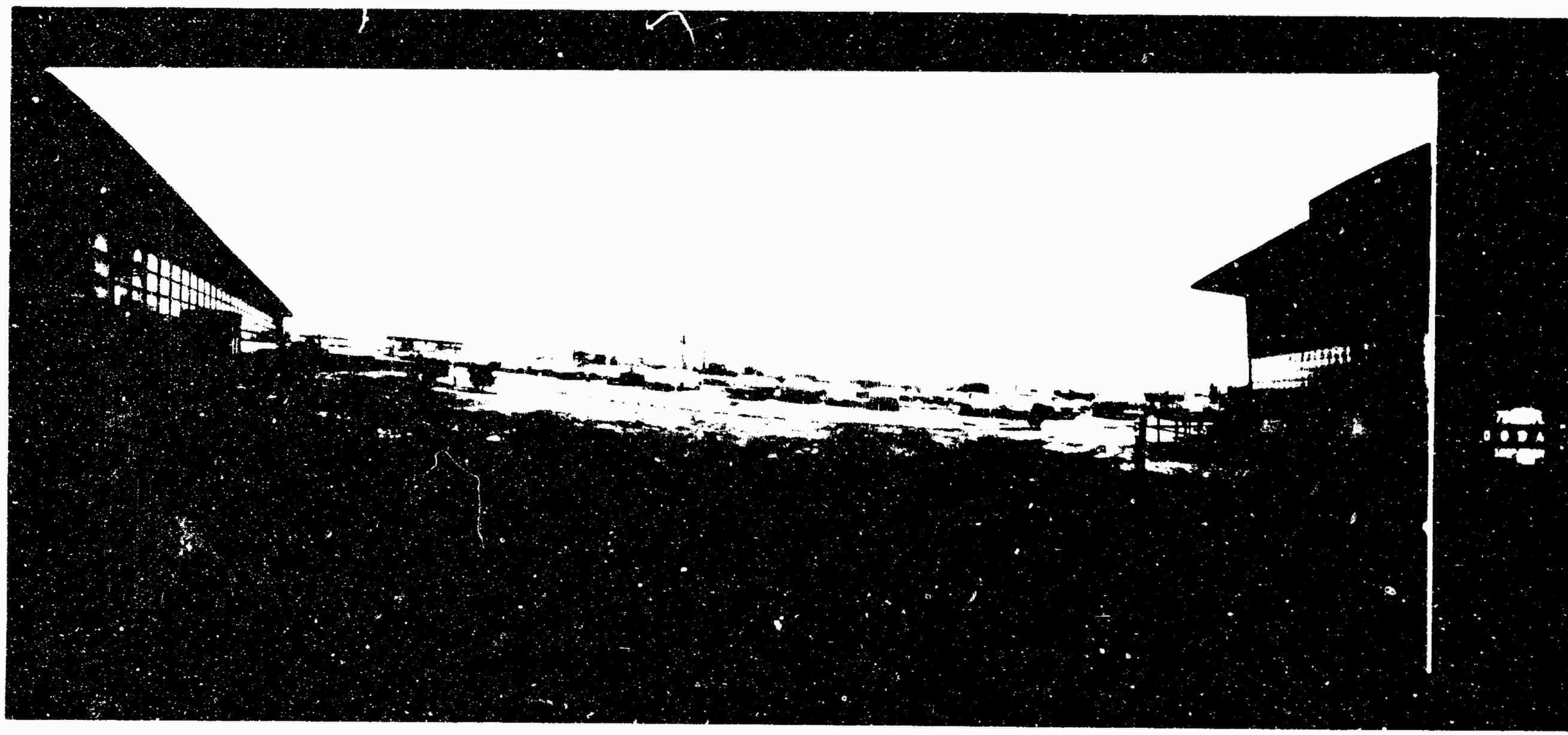


FIGURE 12. FILM FORMAT (SHEET 2 of 2)

c. Timing Fiducial Marks

The timing fiducial marks are recorded every 0.01 second along the fore side of the format. The required design goal accuracy of ±0.001 second was met and exceeded.

Since the accumulative error is greatest at the minimum cycling rate of the camera, wherein approximately 50 fiducial marks are recorded, the maximum accumulative error over the entire 180° scan (first oversized timing dot excluded) will be evaluated for the camera cycling rate of 1 cps only.

The oscillator accuracy = ±0.01% pulse-to-pulse over the temperature range of from +32°F to +158°F (see paragraph 5.2.2e).

$$\text{The maximum accumulative error} = \frac{\pm 0.01\% \times Ti \times N\ Max}{100}$$

where: Ti = Fixed time interval between two marks = 0.01 second

N Max = Maximum number of intervals per film format length

$\approx$ 50 (at 1 cps)

Substituting values in the above equation, we have:

$$\text{The maximum accumulative error} = \pm \frac{0.01 \times 0.01 \times 50}{100}$$

$$= \pm 0.00005 \text{ second}$$

Therefore, the resultant accuracy meets and exceeds the specification requirements by 2,000%.

The maximum accumulative time error of ±0.00005 second when converted into the accumulative distance error will represent approximately ±20 micrometers error over the entire scan of 180° when camera is operating at 1 cps, and approximately ±3 micrometers at the camera cycling rate of 6 cps.

The camera cycling rates above 1 cps can be easily determined from the film negative by measuring distance between the two timing dots and substituting this value in the following formula:

$$N = \frac{D_T}{0.1849}$$

where: N = camera cycling rate (cps)

D_T = distance measured between two timing dots (in)

The above formula should be used only for:

$$D_T > 0.185 \text{ inch}$$

Cycling rates below 1 cps cannot be determined since the distance D_T will be constant for any cycling rate which is below 1 cps.

The above formula is derived from the following relationships:

$$\begin{aligned} vf &= 2\,\omega p\, EFL \\ &= 2\,\omega p\, R \\ &= 2\,\text{Ti}\, R \\ &= 2 \times 3.14159 \times 2.943 \\ &= 18.4914 \text{ in/sec} \end{aligned}$$

where:

vf = Film velocity at 1 cps (in/sec)

ωp = Prism angular velocity at 1 cps (radians/sec)

R = Film Puck radius (in)

EFL = Effective focal length = R (in)

$$N = \frac{Vfn}{vf}$$

N = camera cycling rate (cps)

Since $Vfn = \frac{D_T}{Ti}$

Vfn = film velocity at any cycling rate above 1 cps

$$N = \frac{D_T}{Ti \times vf}$$

Ti = fixed time interval between two consecutive dots

= 0.01 second

Substituting values for Ti and vf, we have:

$$N = \frac{D_T}{0.1849}$$

d. Lens Position Fiducial Mark

The lens position fiducial marks are exposed on the film format. They are flushed simultaneously with the prism degree fiducial marks, every 5° of prism rotation with the accuracy of ±36 seconds of arc, and are recorded on the film every 10° of the panoramic scan with the accuracy of ±72 seconds of arc. The total maximum accumulative error over entire 180° scan does not exceed ±72 seconds of arc. Nineteen (19) fiducial marks are recorded covering full 180° panoramic scan. First mark may not be visible when very wide exposure slits are used. The lens position mark closest to the center of scan is located at the distance of 0.0995 ±0.0003 measured from the imaginary line passing through the centers of the 90° prism fiducial marks. The IMC is phased-in with the prism at the nadir position with the approximate accuracy of ±1 degree. Closer phasing accuracy cannot be obtained at this time (see Section IX, Conclusions, paragraph 5b).

SECTION VI

INSPECTIONS, CALIBRATIONS AND TESTS PERFORMED DURING MODIFICATION

This section contains a description of the inspections, calibrations and tests which had to be performed during the various stages of the final assembly prior to the final acceptanc test.

6.1 PARALLELISM BETWEEN AXIS OF ROTATION OF PRISM, FOCAL PLANE AND EXPOSURE SLIT.

Before the final assembly of the camera body, a number of static measurements were taken and recorded in order to establish the necessary basic dimensional relationship between the axis of rotation of the prism, the focal plane plate, and the exposure slit. During this calibration procedure, the following set-up was used. A heat treated and precision ground shaft was inserted in place of the prism assembly, P/N 1253B12 (former P/N 1076B27). Both ends of the shaft were extending beyond the camera body housing, providing a very accessible and accurate base which simulated axis of rotation of the prism.

With the camera lens axis normal to the surface plate and the shaft parallel to the surface plate within an accuracy of ±0.0001 inch, the necessary "primary measurements" between the shaft axis (simulated axis of rotation of the prism) and the focal plane plate set, P/N 1253-9, were taken and recorded. A secondary set of measurements between the shaft axis and the machined surface of the mounting plate, P/N 1253-20 (former P/N 1076-942) were taken and recorded also. A secondary set of measurements was needed to provide a "frozen" basic dimension - between the shaft and the nearest surface to the focal plane - which will not be affected by subsequent disassembly or the focal plane shimming operations. After the primary and secondary measurements were taken, the camera attitude was changed by 90 degrees.

With the camera focal plane normal to the surface plate and the shaft parallel to the surface plate within an accuracy of ±0.0001 inch, the necessary measurements between the shaft axis and the exposure slit were taken and recorded.

Final angular deviations between the axis of rotation of the prism and the focal plane and the exposure slit were computed later and recorded (see Appendix III, page 105).

6.2 EQUIVALENT FOCAL LENGTH.

In order to determine more accurately the scale of the image produced by the lens, the Equivalent Focal Length (EFL) of the modified camera was measured in accordance with paragraph 5.1.2.2 Method 1 of the MIL-STD-150A, and found to be 75.156mm ±0.05mm (2.9589 inch ±0.0020 inch).

6.3 FOCUSING OF FLASH FIDUCIAL PROJECTION SYSTEM.

Focusing of the flash fiducial projection system was performed at the sub-assembly level in accordance with the instructions contained in the following assembly drawings: Fore Fiducials Projector Assembly, P/N 1253B7, Aft Fiducials Projector Assembly, P/N 1253B6, and Lens Position Fiducial Projector Assembly, P/N 1253B14.

6.4 DENSITY CALIBRATION.

The exposure is the product of the light intensity and the exposure time in accordance with very well know relationship given below:

$$E = I \times T$$

where:

E = Exposure

I = Light intensity

T = Exposure time

Due to severe design restrictions placed by the high density packaging, not much choice was left as far as the selection of the exposure control was concerned. The density of the exposed image had to be controlled either by the variation of the LED brightness or the time of exposure. During the design study, the LED brightness control was selected due to a less complicated, easily accessible and simply calibrated circuitry (only one resistor per each projector had to be replaced during the density calibration procedure in order to change the density of the image). The exposure time was selected to be fixed of approximately 40 to 50 microseconds duration.

The density calibration procedure required a series of photographic tests to be performed at different resistance values determining the magnitude of the forward current. The exposed fiducial dots were analyzed for their size and definition. The final objective of the calibration was to obtain a clearly defined image of a dot point conforming with the design requirements of the Drawing No. 1253-L5, Rev. A. The density value of the focal plane fiducials which were exposed outside of the panoramic imagery was not as critical as the density of the lens position fiducial dot which had to overlap the density of the normally photographed scene.

All exposures were made on plus X Aerecon film type E.K. 8401, developed to a gamma of 1.4. The film was processed in the Kodak Versamat Film Processor, Model 11C with Kodak Versamat 641 chemicals.

Since the nominal densities and their tolerances were not defined in the Statement of Work, the following densities above average base fog of 0.15 were assigned after evaluation of test results: 1.6 ±0.3 for the prism degree fiducials, 1.8 ±0.3 for the timing fiducial; 2.3 ±0.3 for the center of scan identification fiducial and 3.0 ±0.3 for the lens position fiducial. For the sake of future reference, we must add that the maximum density value for the prism degree and the timing fiducials should never be made greater than 2.6 since beyond this value the diameter of the dot will increase and a halo effect will be visible (i.e., at the density of 3.6 the diameter of the dot was measured to be 0.020 inch which is a 100 percent increase from the nominal dot diameter of 0.010 inch diameter).

As far as the density of the lens position marker is concerned, the selected value of 3.0 ±0.3 may be increased in the future if required to 3.6 in accordance with our test data. However, in order to obtain this high density value, the forward current will have to be increased from the present value of 2mA to 200mA. What effect this would have on the life of the LED cannot be determined until an extensive series of life tests are performed. A special breadboard simulating the actual system operation would have to be built in order to obtain a sufficient data relating several different densities with the corresponding current values.

For the time being, the density of 3.0 ±0.3 proved to be sufficient. This statement is based on the conclusions reached after evaluation of the test data obtained during the outdoor photographic tests which was performed after the final acceptance test.

This test was witnessed by the RADC representatives and is described in Section VIII, paragraph 8.1.

6.4.1 Density Measurements

The measurement technique used to arrive at the density values for each dot consisted of making microdensitometer traces of a representative sampling of dots and then averaging the distribution of energy on the negative. Traces of the dots were made of the GAF Model 4 Automatic Recording Micro-densitometer. A typical trace for a prism degree dot point is shown in Figure 13. To scan the dot, a circular aperture of 24 microns was used. A principle of average value was used to determine the density. In effect, the curve was integrated for a 250 micrometer diameter dot. A centrally located rectangle was drawn with a width of 250 micrometers and a height equal to the peak density value "A". Using the planimeter, the area under the dot curve lying within the 250 micrometers width was measured, as well as the area of the rectangle. The density was then found using the following formula:

$$\text{Density} = \frac{\text{Shaded area under dot point within rectangle BCDE}}{\text{area of rectangle BCDE}} \times A$$

6.5 RECORDING OF ACTUAL EXPOSURE TIME.

The Polaroid camera recordings illustrating instantaneous rise, the constant illumination level time (actual exposure time) and decay time are presented in Figure 14. The scales are as follows:

Horizontal Sweep - 20 microsecond/division

Vertical Sweep - 5 volts/division

The following actual exposure times were recorded:

50 microseconds for the prism degree fiducials

50 microseconds for the timing fiducial

50 microseconds for the center of format identification fiducial

40 microseconds for the lens position fiducial

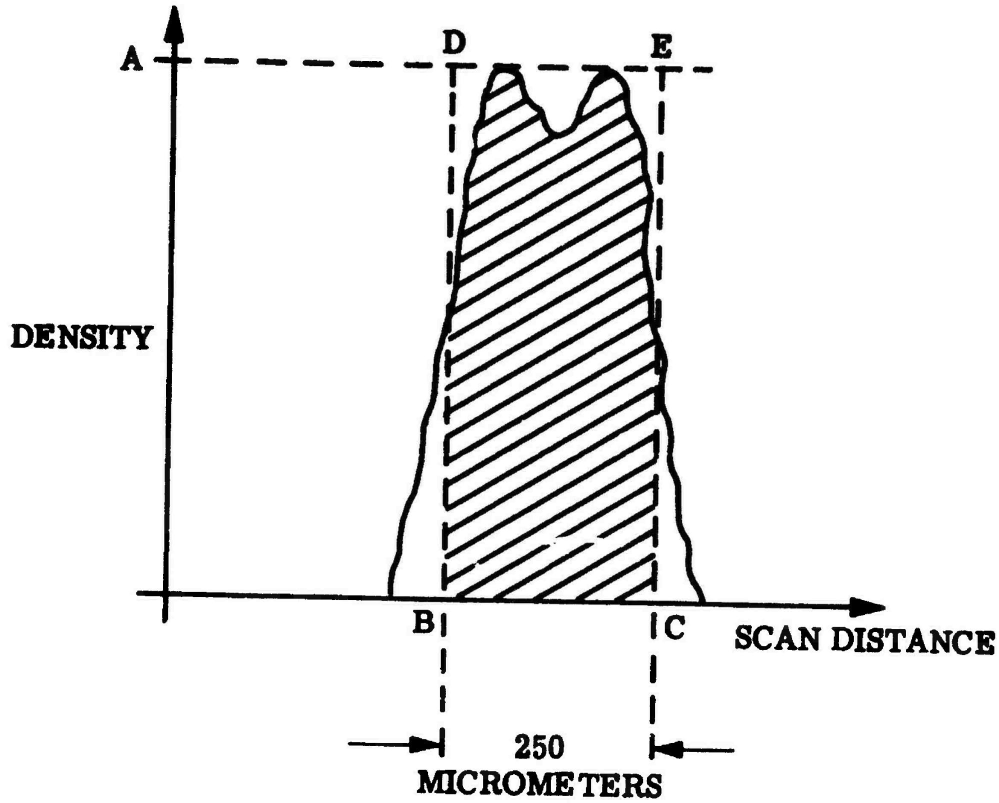
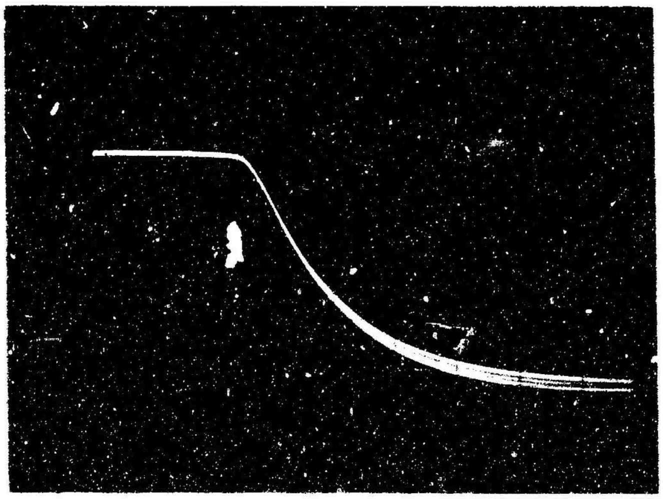


Figure 13. Trace of Dot (Above Base Fog)

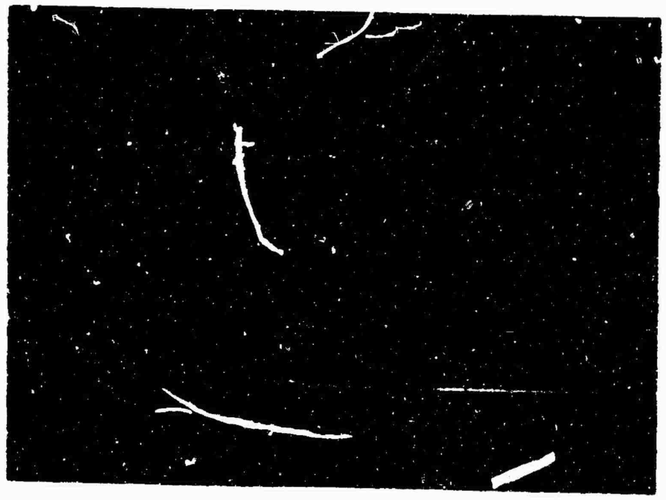
PRISM DEGREE MARK



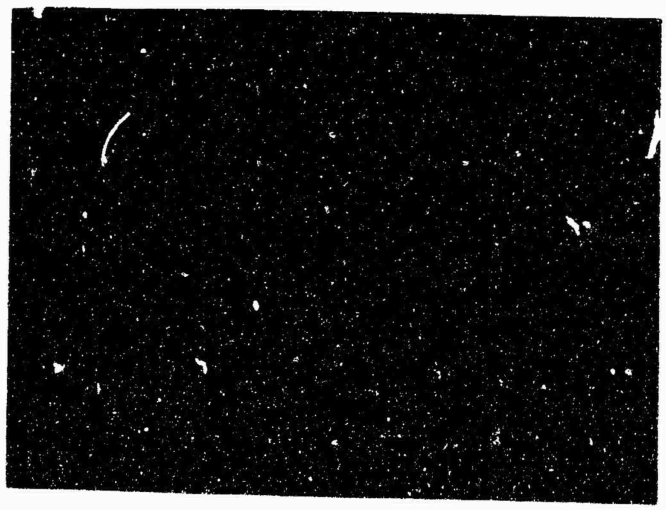
TIMING MARK

SCALE:
HORIZONTAL SWEEP: 20 MICROSECONDS/DIV
VERTICAL SWEEP: 5 VOLTS/DIV

Figure 14. Exposure Time, Test Data (Sheet 1 of 2)



LENS POSITION MARK



CENTER OF SCAN MARK

Figure 14. Exposure Time, Test Data (Sheet 2 of 2)

6.6 STATIC BALANCING OF LENS-WOBBLE PLATE ASSEMBLY.

In order to compensate the weight of the added modifications located on the camera lens and consisting of the lens cover, P/N 1253-3, lens position fiducial projector assembly, P/N 1253B14, terminal board assembly, P/N 1253B8, and the miscellaneous attaching hardware, a static balancing was performed at the sub-assembly level in accordance with instructions contained in Drawing No. 1253B13. The test results indicated that the added "design weight" of counterweight assembly, P/N 1253B22 was not sufficient and an additional weight of approximately one (1) ounce had to be secured to the P/N 1253B22 in order to meet the design requirements. We would like to point out, however, that the static balancing of the IMC system does not eliminate a "reversed couple effect" which exists in the system due to the dynamically unbalanced translating mass of the lens and the lens counterweight. The camera system when designed was never intended to be used in a stabilized mount, and, therefore, should never be considered to be adaptable for this type of mounting.

SECTION VII

FINAL INSPECTIONS, TESTING, AND CALIBRATIONS

In order to comply with the requirements of paragraph 4.3 of the Statement of Work PR No. I-2-4039, the FSDS's Quality Control Department performed the necessary inspections, testing and calibrations of the modifications in accordance with Acceptance Test Procedure Specification (ATPS) No. ED-EB-75. The camera modifications were given a thorough mechanical and visual inspection to determine that the quality of material and workmanship was in compliance with the requirements. The camera was given all electrical tests necessary to confirm that the added circuitry was inherently sound and in compliance with the design requirements, and the camera could be used in military aircraft.

The results of the inspections, tests and calibrations covered by the ATPS No. ED-EB-75 are contained in Appendix III.

SECTION VIII

TESTS AND CALIBRATIONS NOT COVERED BY ATPS

During the final inspection and testing which was witnessed by two governmental representatives, the following additional photographic tests and calibrations not covered by the requirements of the ATPS were performed at the request of the RADC Project Engineer, Mr. J. Callander.

8.1 PHOTOGRAPHIC TESTS.

The camera magazine was loaded with 500 feet of live film, Type EK8401, and the camera system together with the power supply and the camera system test console was taken outside the plant. The camera body with the attached magazine was placed on its side so that the lens would cover approximately one half (1/2) of the sky and one half (1/2) of the terrain background. Approximately 50 exposures were made at different cycling rates.

The camera system was then taken inside the plant and operated at 1, 2, 3, 4, 5, and 6 cycles per second. Approximately twenty good exposures were recorded at each cycling rate. A clear background was provided for the fiducial imagery exposed at 1, 2, and 3 cycles per second. A purposely fogged background was provided for the fiducial imagery exposed at 4, 5, and 6 cycles per second, with the background density variable with the cycling rate.

The exposed film was processed at FSDS to a gamma of 1.4 and the entire roll of 500 feet of the processed film was given to Mr. J. Callander.

8.2 CALIBRATION OF PERIPHERAL RESEAU.

The exposed prism degree fiducial marks can be utilized as a peripheral longitudinal reseau pattern, provided than an exact longitudinal distance between two projected fiducial marks is known. This distance was calibrated in accordance with standard procedures, exposing VF Spectroscopic Plates in contact with the focal plane while the prism degree fiducials were fired. Data was read on the Mann Comparator with the Data Logger. The measured distance was found to be 110.989mm. The accuracy of the reading was within ±0.015mm.

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SECTION IX

CONCLUSIONS

The conclusions for this project are as follows:

1. The feasibility of constructing a miniature state-of-the-art flash fiducial film marking system providing each frame of imagery with information pertinent to the orientation and operating position of the sensor has been demonstrated.

2. The fiducial marks generated by the system and recorded on the moving film have sufficient optical density and definition to reproduce on subsequent photographic reproductions.

3. Easily accessible LED brightness controls proved to be a great asset during the density calibration procedure.

4. The nominal center of frame in the "Y" direction may vary from magazine to magazine within a tolerance of +0.031 to -0.022 inch. Installation of dowel pins at the camera-magazine interface and a more accurate positioning of the magazine platen should be considered in the future in order to control the location of the fiducial dots with respect to the film perforations.

5. The implemented modifications did take the form of auxiliary information gathering by means of additional hardware rather than a change in the design of operational concept of the camera. However, we must conclude that a much more accurate internal calibration of the camera could have been obtained if the following design changes were made:

   a. Change in the operational concept of the shutter wherein the maximum and the minimum exposure slit width would be symmetrical about the plane of symmetry of the camera. Central location of the exposure slit would allow the lens position mark projector to generate an accurate trace of the principal point.

b. Redesign of the "prism-film transport puck" and "prism-IMC shaft" gear trains to include means for very accurate phasing adjustment between the prism, film transport puck and the IMC shaft. The new redesigned gear train should consist of precision class 3 gears in order to minimize both "tooth-to-tooth" and "runout" errors which are contributing to the velocity variations. Tooth-to-tooth error contributes to minor incremental velocity variations within the frame, and the runout error contributes to the velocity variation between two consecutive frames.

6. Frame to frame variations measured on exposed and processed negatives show on average a difference of approximately 0.030 inch (762 micrometers) between the lengths of two consecutive formats covering 180° scan. However, if numbers were assigned to each frame, all frames identified by the even numbers would show a very insignificant difference between their format lengths; the same principle applies to all frames identified by the uneven numbers. The obvious conclusion is that there must be a repetitive and cyclic velocity error in the prism-film transport puck gear train. The mechanical analysis of the prism-film transport puck gear train indicates that the cyclic velocity error can be attributed only to a gear runout, caused to some degree by previous camera usage (the modified camera life counter shows approximately 70,000 cycles accomplished since last overhaul which was performed in 1971).

7. During the IMC stroke, the principal point does not translate along a straight line parallel to the direction of flight, but instead traverses an arc of 3.5-inch radius. This results in a small phasing error of the IMC. This small error which was discussed in detail in Section III, paragraph 3.3.2a is negligible in tactical reconnaissance usage for which the camera system was originally designed, however it should be taken into consideration in metric applications.

8. The test results indicate that the exposure time of the fiducial marks, which is now set at 50 microseconds maximum, can be safely decreased to approximately 5 microseconds if required. This would reduce the present image smear from 0.0009 inch (23 micrometers) to 0.00009 inch (2.25 micrometers) for a cycling rate of one (1) cps, and from 0.0055 inch (141 micrometers) to 0.00055 inch (14 micrometers) for a cycling rate of six (6) cps. The maximum possible image smear of 0.0055 inch at six (6) cps may seem to be completely out of order when

compared with the reading accuracy requirements encountered in photogrammetry. However, one must realize that at the cycling rate of 6 cps the fiducial dots are being recorded on the film moving at the velocity of 111 inches per second. A simple measuring technique which insures the required photogrammetric accuracy is recommended in the next section.

9. A common modification design approach is applicable to both the KA-56B and the KA-60C cameras with the following exceptions pertaining to the KA-60C camera modification.

   All mechanical, electrical and optical components to be used in the possible future modification of the KA-60C camera will have to be "scaled down" versions of the components used in the KA-56B modification. The flash fiducial firing and driving circuitry will have to be either of integrated type if packaged inside the camera body or similar to the KA-56B circuitry if packaged outside the camera. The final physical dimensions of the package and the type of circuitry used will depend upon the "camera space" available in the vehicle selected for the camera installation. The development and fabrication of the full integrated circuitry will be economical only if large production quantities will be considered in the future.

SECTION X

RECOMMENDATIONS

The following program is recommended as the logical continuation of the work performed under this contract:

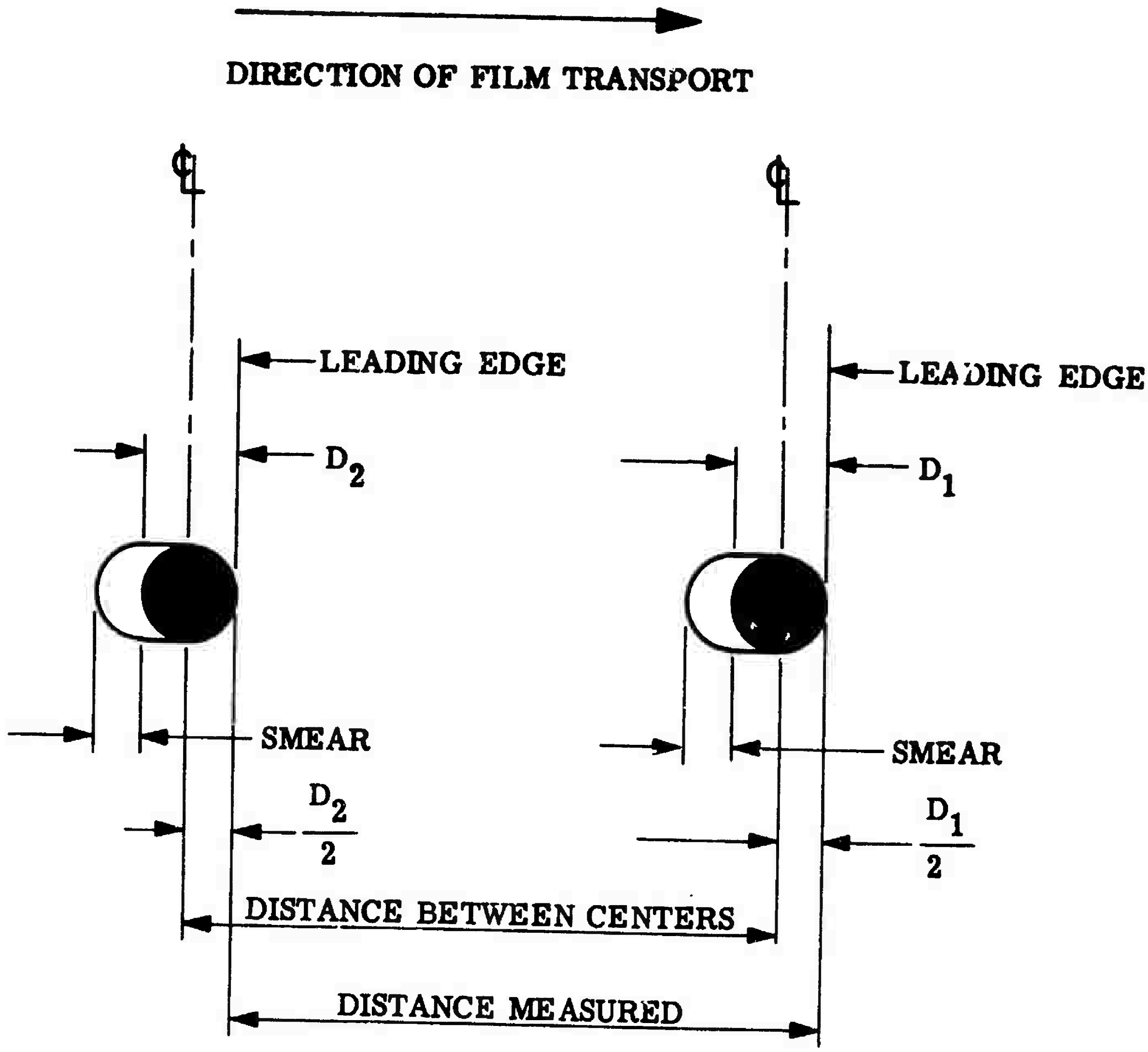
Flight tests are recommended to prove conclusively that the mechanical, electrical and optical performance of the implemented modifications meets all the specification requirements under actual flight conditions. These test flights should be conducted in accordance with the following suggested camera operational configurations tabulated below:

Ground Speed V Knots	Altitude H ft.	$\frac{V}{H}$ knots ft.	Cycling Rate CPS	Nominal Overlap %	Actual Overlap %
600	250	2.4	6	56	52
450	1,000	0.45	1.125	56	52
450	3,000	0.15	1	83	79
450	5,000	0.09	1	90	86

Camera mode selection and overlap characteristics for the modified camera are presented in Appendix V.

A simple distance measuring technique which completely ignores image smear of fiducial dot recorded on the film, and at the same time insures the required photogrammetric accuracy is recommended herein for all photography taken at low altitudes of 250 ft. at the cycling rate of six (6) cps. The recommended technique recognizes only the "leading edges" of the fiducial dots and abandons completely the normally accepted center-to-center measuring technique utilized in stationary film framing photography. As long as the direction of the film transport is known, the "leading edge" (see Figure 15) of the dot is easily identified and the measurement between the leading edges of two dots can be taken very accurately.

For this system, the exact center of each dot is always



$$D_1 \equiv D_2$$

$$\frac{D_1}{2} \equiv \frac{D_2}{2}$$

Figure 15 Measurement Technique

located at the distance of $D_1/2$ or $D2/2$ measured from the leading edge of the respective dot, and, therefore, the distance measured between leading edges of D_1 and D_2 is equal to the distance between the centers as shown in Figure 15 since $D_1 = D_2$, and $\frac{D_1}{2} = \frac{D_2}{2}$.

SECTION XI

BIBLIOGRAPHY

Technical Manual, Service Instructions
Still Picture Camera KA-56A, KA-56B
KA-56B1, KA-56C, KA-56D, KA-56E
and 1,000 Foot Film Magazine
Part No. 1107B100 .... (USAF)T.O. 10A1-5-25-2

Technical Manual, Overhaul .... (USAF)T.O. 10A1-5-25-3

Technical Manual, Illustrated
Parts Breakdown .... (USAF)T.O. 10A1-5-25-4

KA-56 Panoramic Camera Systems
Operating Manual................ (Fairchild) SME-KB-9

Technical Manual, Operator and
Organizational
Maintenance Manual Including
Repair
Parts and Special Tool Lists
Camera, Still Picture KA-60C.... (US Army)TM11-6720-242-12

Technical Manual, DS, GS and Depot
Maintenance Manual Including Repair
Parts and Special Tools List
Camera, Still Picture KA-60C.... (US Army)TM11-6720-242-35

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APPENDIX I

INCOMING INSPECTION AND TEST RESULTS

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<u>INCOMING TEST REPORT</u>

KA-56

Camera No. 65-2165
J-Box No. 65-625
Magazine No. 66-126

July 19, 1972

INCOMING TEST

OPTRONICS LABORATORY

Data Sheet No. DS-OL-6

26 December 1967

KA-56 CAMERA SYSTEM

Camera No. 65-2165 Magazine No. 66-126

J-Box No. 65-625 Cassette No. ---

	Inspection Stamp
1. Metering	
a) Picture area (approximately 4.5" x 9.4")	Acc.
b) Pitch (10.872 $^{+.125"}_{-.022"}$)	Acc
2. Frame Counter	
a) Imaged	Acc
b) Focus	Acc
c) Operating	Acc
d) Counter Blur at 6 cps (V/H 120)	Acc
3. Center of Format Marker	
a) Imaged	REJECTED
b) Location	REJECTED
4. Banding	Acc
5. Scratching, Static, Abrasions, etc.	Acc
6. Light Leak	Acc
7. Slit Width	Acc

Tested by: [signature]

Approved by: [signature]

FOR REWORK

Date 7-19-1972

Acceptance Stamp

N/A

Data Sheet No. DS-OL-6

26 December 1967

Test A IMC Rate 5.908"/sec.

Frame	1	2	3	4	5	6	7	8	9	10
Resolution	25	24	24	22	21	24	22	25	25	24

Frame	11	12	13	14	15	16	17	18	19	20
Resolution	20	19	20	20	23	25	23	25	23	20

Test B IMC Rate 2.949"/sec.

NOT TESTED

Frame	1	2	3	4	5	6	7	8	9	10
Resolution										

Frame	11	12	13	14	15	16	17	18	19	20
Resolution										

Data Sheet No. DS-OL-6

26 December 1967

Test C IMC Rate 1.962"/sec. Not Tested

Frame	1	2	3	4	5	6	7	8	9	10
Resolution										

Frame	11	12	13	14	15	16	17	18	19	20
Resolution										

Test D IMC Rate 1.469"/sec.

Frame	1	2	3	4	5	6	7	8	9	10
Resolution	32	27	27	26	23	29	31	29	22	31

Frame	11	12	13	14	15	16	17	18	19	20
Resolution	36	30	29	23	27	27	25	25	33	31

Percentage of all photography meeting resolution requirement of acceptance test table equals - minimum acceptable level is 90%.

	Minimum Resolution	Slit Width	
A 25 %	25 L/MM	.055" +.027" -.014"	.250"
B N/A %	29 L/MM	.026" +.014" -.007"	N/A
C N/A %	32 L/MM	.019" +.009" -.005"	N/A
D 5 %	34 L/MM	.019" +.009" -.005"	.020"

Incoming Inspection on KA-56
System S/N 65-2165

The following discrepancies are noted:

1. Top of Focal Plane

   a. Burrs at dowel pin
   b. Burrs on two screws
   c. Burrs on surface

2. AEC- Painted Surface Scratched

3. Glyptol missing from Screws at:

   a. Data tube holder (top surface)
   b. 10-32
   c. ADAS clamp eccentric

4. Nut missing, 4-4D Set Screw, ADAS Cam Follower Arm

5. Adjustment of Screw on Micro-Switch Bracket N. G.

6. Cover Handle Bent

7. Cleaning Required

8. Center of Format Bulb Burned Out

9. Cycling Rates Slow (Below Spec. Minimum)

Inspector: [illegible]

Date: 1/19/72

APPENDIX II

MINUTES OF THE DESIGN APPROVAL CONFERENCE

FAIRCHILD
SPACE AND DEFENSE SYSTEMS
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

300 ROBBINS LANE, SYOSSET, L.I., NEW YORK 11791 • 516 WE 1-4500 • TWX 510 221-1836 • CABLE FAIRCAM SYOSSET NEW YORK

5 September 1972
Refer: 2820

Rome Air Development Center
Headquarters, Air Force Systems Command
Griffiss Air Force Base, New York 13440

Attention: Mr. R. Murad/RADC/PMA

Subject: Contract F306-72-C-0374

Gentlemen:

Enclosed are three (3) copies of Exhibit "A" entitled, "Minutes of Design Approval Conference."

This meeting, which was held at our facility on 29 August 1972, was to present the results of our design study on the KA56 Modification, and to obtain the concurrence of the Government to the design layouts.

Both of these items were successfully completed.

Very truly yours,

Joseph G. Kraljic

Joseph G. Kraljic
Contracts Administrator

JGK/pg
Enclosure.

Exhibit "A"

Minutes of Design Approval Conference

Contract F03602-72-0374

A meeting was held on 29 August, with the following RADC and FSDS personnel in attendance: Dr. J. DelVecchio and Mr. J. Callander representing RADC, and Mr. H. Hastings and J. Daszkowski representing FSDS.

The technical presentation was accomplished in accordance with the attached agenda of the meeting. The presentation was followed by a period of questions and answers and a general discussion encompassing (a) design problems, (b) compliance with the Statement of Work PR No. 1-2-4039, (c) compliance with FSDS Proposal No. ED-CB-179, and (d) the maintenance of the modified system.

Dr. DelVecchio and Mr. J. Callander agreed that the modified system will consist of the following Government Furnished Property:

- Camera Body, Part No. 1076B200, Serial No. 65-2165
- Camera Magazine, Part No. 1087B1, Serial No. 66-126
- Camera Control Unit, Part No. 1076E100, Serial No. 65-625

During the meeting, the following modification design layouts were reviewed and approved by RADC representatives:

• Flashed Fiducials Layout	Drawing Number 1253L1
• Encoder Assy, Prism Modification Layout	Drawing Number 1253L2
• Film Marking Elec Components Packaging	Drawing Number 1253L3
• FMC Tracer Layout	Drawing Number 1253L4
• Film Format Layout	Drawing Number 1253L5
• Electrical Schematic, KA-56B Mod.	Drawing Number 1253SD1

The RADC representative agreed that FSDS should proceed immediately with the detail design, purchase of the commercial hardware and fabrication of parts.

Non-Compliance with the Statement of Work PR No. 1-2-4039

The RADC Representative approved the following changes:

(a) Recording of timing marks paragraph 4.2.1.1.3 Statement of Work PR. No. 1-2-4039.

- Delete last sentence and substitute the following: "The timing marks shall be recorded every 0.01 seconds with an accuracy of ±0.001 seconds relative to the first timing mark. The first timing mark will be flashed within 0.01 second mark relative to the time at beginning of scan."

(b) Recording of the Center of Scan Marks, paragraph 4.2.1.1.2. Statement of Work, PR No. 1-2-4039.

- Delete sentences and substitute the following: "An identification mark shall be flashed at the center of scan" in the vicinity of the 90° prism degree marker."

Recording of the FMC Trace

An agreement was reached that the FMC markers will be flashed simultaneously with the prism degree markers utilizing the same signal from the encoder.

FSDS Suggested Modifications and Calibration (See Attached List)

Mr. J. Callander after receiving FSDS suggested modifications, suggested that unsolicited proposals be submitted for the following:

- Calibrated Focal Length
- Calibrated prism degree markers longitudinally
  (In the direction of flight)
- Fiducial Size 35 to 50 micrometers.

Miscellaneous:

(a) Mr. J. Callander requested that the film negative with recorded imagery generated by the new film marking system be delivered to him approximately one week before the Acceptance Test. This is acceptable to FSDS.

(b) It was agreed that FSDS will replace a broken data recording mirror Part Number 1076-261 at additional cost to the Government.

(c) The RADC representatives asked us if it will be possible to freeze ADAS data at the time when the nadir fiducials are fired. FSDS did promise to investigate this matter.

AGENDA

KA-56 MOD. DESIGN APPROVAL CONFERENCE

1.	INTRODUCTION
2.	GOVERNMENT FURNISHED PROPERTY-QA REPORT
3.	MODIFICATION FEASIBILITY STUDIES
4.	DETAILED TECHNICAL DISCUSSION OF THE MODIFICATION
4.1	NEW FILM FORMAT WIDTH OF 4.188 In.
4.2	PRISM DEGREE MARKERS, CENTER OF SCAN MARKERS, FMC MARKER
4.2.1	FLASHING CONTROL
4.2.2	PROJECTION
4.2.3	GEOMETRY AND LOCATION
4.3	FMC MARKERS
4.3.1	FLASHING CONTROL
4.3.2	PROJECTION
4.3.3	GEOMETRY AND LOCATION
4.4	TIMING MARKS
4.4.1	FLASH CONTROL
4.4.2	PROJECTION
4.4.3	GEOMETRY AND LOCATION
4.5	PACKAGING

.6 ACCURACIES INVOLVED IN THE MODIFICATION AND CALIBRATION

5. SUGGESTED MODIFICATIONS AND CALIBRATIONS AT ADDITIONAL COST.

6. QUESTIONS AND ANSWERS

SUGGESTED MODIFICATIONS AND CALIBRATIONS AT ADDITIONAL COST

1) Install dowel pins between the camera body and the magazine.

2) Redesign shutter mechanism as follows:

   - Bring stationary edge of the slit within .010 of the optical center

     Redesign AEC circuitry accordingly

   Note: This modification will allow FMCtrace to be recorded without distortion.

3) Refurbish camera system

4) Calibrate lens

   a) Radial & tangential distortions

   b) Effective Focal Length

   c) Calibrated Focal Length (scale control)

5) Calibrate prism degree markers longitudinally (Direction of Flight) to provide peripheral reseau.

PRELIMINARY ACCURACIES ASSIGNED IN THE MODIFICATION OF THE KA-56 B CAMERA

REV. A   J.D. 8/30/72

Timing Marks	Flashed continuously every 0.01 sec. with an accuracy of ± .001 sec. relative to the first timing mark. The first timing mark will be flashed within 0 .01 second relative to the beginning of the scan. (A) was ±.01
Prism Degree Marks/	Flashed during the photographic portion of the scan every 5 degrees of the prism rotation with an accuracy of ± 30 seconds of an arc
Center of Scan Mark	Identification mark flashed at the center of scan (close accuracy not required)
FMC Trace Marks	Flashed simultaneously with the prism degree marks, with the same accuracy of ± 30 seconds of an arc.

APPENDIX III

OUTGOING INSPECTION AND TEST RESULTS

FINAL ACCEPTANCE TEST REPORT

KA-56/Mod.

Camera No. 65-2165/M
J-Box No. 65-625
Magazine No. 66-126

March 22, 1973

Fairchild Space & Defense Systems
A Division of Fairchild Camera & Instrument Corporation
Syosset, New York

Quality & Reliability Department

MODIFIED KA-56 CAMERA SYSTEM

PSD Acceptance Test Procedure LD-EB-75

FINAL ACCEPTANCE

FSDS ORDER NUMBER 2820-700 DATE 9/22/78

1. Nameplates secured & properly marked

		Serial No
A.	Panoramic Camera, KA-56/M	65-2165/M
B.	Camera Body	65-2165/M
C.	Camera Magazine	66-126
D.	Camera Control Unit	65-625

2. All external connectors have dust covers ✓ FCI 1712
3. Life counter (in camera body) reading 072800
4. Check - MGFE for -
   a) Finish NG-As rec'd from Customer ✓ FCI 1712
   b) Workmanship (Of modifications Only) ✓ FCI 1712
   c) Completion of Assembly " " FCI 1712
   d) Cleanliness As rec'd from Customer FCI 1712

5. Weight less spools — App 68#

6. Check for dust covers for following

   a) Camera Body 1076-B67 — ✓ FCI 1712

   b) Camera Body 1076B83 — ✓ FCI 1712

   c) Camera Magazine 1076-598 — ✓ 1712

	FCI
Acceptance	FCI 1712
Date	3/23/73

Fairchild Space & Defense Systems
A Division of Fairchild Camera and Instrument Corporation
Syosset, New York

Quality & Reliability Department

MODIFIED KA-56 CAMERA

FSD Acceptance Test Procedure ED-EB-79 Rev. ________

FSDS Order No. 2820-700 Date 2-23-73

Assigned No. 65-2165

TRANSPORT TEST

1. 500 feet dummy film loaded in magazine ________
2. 115 volt 400 cps ± 3% input voltage reading 115.0 volts
3. 27.5 ± 1% D.C. voltage reading 27.5 volts

Command Voltage	Rate Cycles/Second	Cycles Tolerance	Actual Cycles/Sec
15.0	1	0.92 - 1.08	1.03
20.02	1	0.92 - 1.08	1.02
60.11	3	2.81 - 3.19	.349
80.15	4	3.78 - 4.22	.262
100.19	5	4.76 - 5.24	.209
120.22	6	5.76 - 6.24	.174
150.00	6	5.40 - 6.60	.170

5. Film fail lamp on at end of film FCI 226
6. Transported 500 feet film FCI 226

Acceptance Stamp

FCI 226

Date 2-23-73

Name M. Pine

Fairchild Space & Defense Systems
A Division of Fairchild Camera & Instrument Corporation
Syosset, New York

Quality & Reliability Department

MODIFIED KA-56 CAMERA

FSD Acceptance Test Procedure Rev. ________

FSDS Order No. 2820-700 Date 5/3/73
Assigned No. ________

SIMULATED IN-FLIGHT PERFORMANCE TEST

1. 115 volt 400 cps ±3% input voltage reading 115 volts
2. 27.5 ± 1% D.C. voltage reading 27.5 volts
3. Magazine loaded with live film in accordance with specification FCI 2830
4.

Test	V/H Voltage	V/H Set	Inspection Stamp
A	59.77	59.77	FCI 2830
B	14.864	14.864	FCI 2830

DEVELOPED FILM CHECK

5. Metering
   a) Format area approximately 4.18 x 9.25 inches FCI 2830
   b) Pitch 10.872 ±0.5 inches FCI 2830

Form 163CB-QC, M

6. Resolution

Test A IMC Rate 5.098"/sec.

Frame	1	2	3	4	5	6	7	8	9	10
Resolution	25	30	27	28	28	28	28	28	26	26

Avg.: 27

Test B IMC Rate 1.469"/sec.

Frame	1	2	3	4	5	6	7	8	9	10
Resolution	35	35	36	36	36	36	30	33	36	34

Avg.: 35

7.	Banding	FCI [illegible]
8.	Scratching	FCI 2830
9.	Light Leak	FCI 2830
10.	Data Annotation	
	a. Imaged	FCI 2830
	b. Focus	FCI 2830
	c. Location	FCI 2830
11.	Center of Format Identification Marker	
	a. Imaged	FCI [illegible]
	b. Location	FCI [illegible]
	c. Focus	FCI [illegible]
12.	Prism Degree Markers	
	a. Imaged	FCI 2830
	b. Location	FCI [illegible]
	c. Focus	FCI [illegible]
13.	Timing Markers	
	a. Imaged	FCI [illegible]
	b. Location	FCI [illegible]
	c. Focus	FCI [illegible]
14.	FMC Trace Markers	
	a. Imaged	FCI [illegible]
	b. Location	FCI [illegible]
	c. Focus	FCI [illegible]

Acceptance Stamp FCI

Date 3/21/73

Name [illegible]

TESTS AT VARIOUS V/H RATES WERE PHOTOGRAPHED BOTH INDOORS AND OUTDOORS. THESE EXPOSURES WERE FURNISHED THE CUSTOMER FOR HIS EVALUATION ON 3-13-1973. [illegible]

Fairchild Space & Defense Systems
A Division of Fairchild Camera & Instrument Corporation
Syosset, New York

Quality & Reliability Department

MODIFIED KA-56 CAMERA

PSD Acceptance Test Procedure ED-EB-79 Rev. ________

FSDS Order No. 2620-700 Date 1-15-73
Assigned No. ________

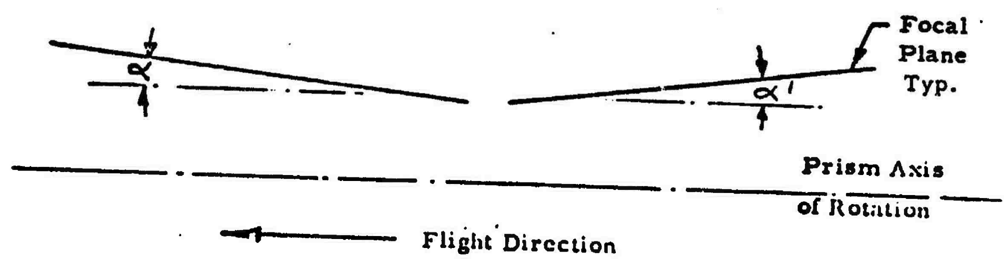
CALIBRATION DATA

Ambient temperature : 75° F ± 5°F

Accuracy of measurements : ± 10 arc sec.

1. Parallelism of the axis of rotation of the prism and the focal plane plate

$\alpha = 0°\ 0'\ 55''$ $\quad\alpha' = \_\_°\ \_\_'\ \_\_''$



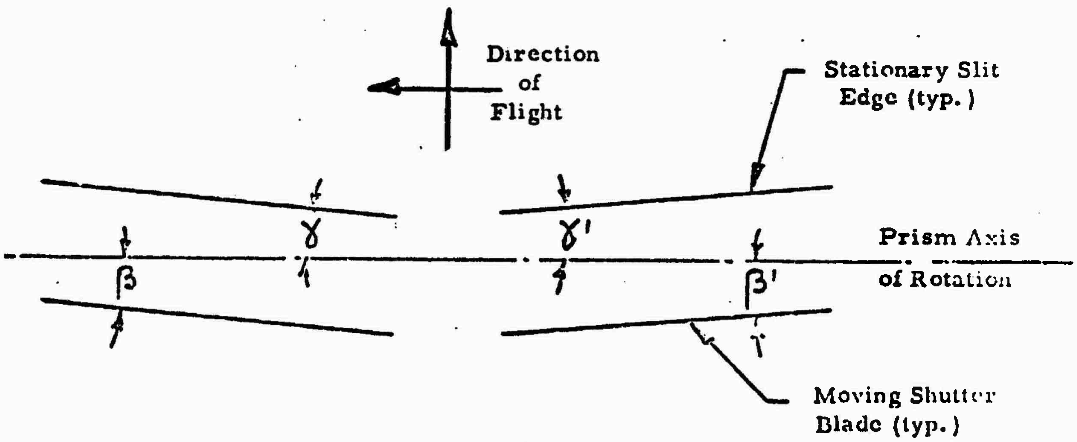
FCI 825

2. <u>Parallelism of the axis of rotation of the prism and the exposure slit (shutter blade)</u>

$\beta =$ ___° ___' ___" $\beta' =$ 0° 1' 43"

$\gamma =$ ___° ___' ___" $\gamma' =$ 0° 0' 31"

Ⓐ Direction of Film Transport Ⓐ Film emulsion down



Inspection Stamp | FCI 125

Name Ernest Beltram

Date 1/15/73 J.D.

Form 158E-QC/M

Fairchild Space & Defense Systems
A Division of Fairchild Camera & Instrument Corporation
Syosset, New York

Quality & Reliability Department

MODIFIED KA-56 CAMERA

PSD Acceptance Test Procedure ED-EB-79

Ⓐ FSDS Order No. 2820-700 Date 2-23-73
Assigned No. ______

SLIT WIDTH TEST

1. Adjust and record AEC potentiometer voltage for foot lamberts

Ft. Lamberts	AEC Pot. Volts
155	2.36
310	3.86
620	6.08

2.

Test	A
V/H Volts	59.770
Limits	.041-.082
Light Increasing to 310 Ft. Lamb.	.061
Light Decreasing to 310 Ft. Lamb.	.061

3.

Test-V/H 14.864	Limits	Reading
Cloud Cover - 25%	0.028-0.056	0.045
Cloud Cover - 50%	0.056-0.112	0.091

4. Cloud Cover Function
   A. Thru camera control simulator FCI 226
   B. Thru test connector FCI 226

Acceptance Stamp

Date 2-23-73
Name DDV'ccone

FCI 226

Fairchild Space and Defense Systems
Quality Assurance Department
Aerospace Test Section
Optronics Laboratory

Test Report

Camera Type: KA-56 Mod.

Camera S/N: 65-2165 M

Date: 9 April 1973

Compiled: ______________
Hans Jednat

Approved: ______________
Marvin Rosenberg

I. **Equivalent Focal Length**

Calibration per method I of Paragraph 5.1.2.2, Mil STD 150A at 70° F on VF Spectroscopic Plates.

EFL= 75.156 mm ± 0.050 mm

II. **Prism Degree Marker Separation**

Performed at 70° F on VF Spectroscopic Plates.

Prism Degree Marker Separation: 110.989 mm ± 0.015 mm

III. **Film Marking System (Ref. B/P 1253L5, Rev. A)**

Two Frames of EK 8401 processed in a Model 11C EK Versamat to a a gamma of 1.4 were analyzed.

Test Parameters:

Command Voltage ±.05	Slit Width (In.)	Cycling Rate (CPS)	Cycle Period (Secs.)
20.02	.030"	1	1.02
120.22	.120"	6	0.174

Test Results:

	Peak Density 1 CPS		6 CPS	
	Frame 1	Frame 2	Frame 1	Frame 2
Prism Degree Marker(Fore)	1.66	1.75	1.69	1.98
Prism Degree Marker (AFT)	1.69	1.72	1.69	1.88
Center of Scan Marker	2.4	2.41	2.68	2.42
Timing Marker	2.02	2.03	2.02	2.12
Lens Position Marker	2.85	2.90	3.02	3.22

Average Base Fog: 0.15

Test Results:

Dot Diameters (inches)

	1 cps		6 cps	
	Frame 1	Frame 2	Frame 3	Frame 4
Prism Degree Marker (fore)	.010	.009	.010	.011
Prism Degree Marker (aft)	.010	.010	.010	.010
Center of Scan Marker	.012	.011	.011	.011
Timing Marker	.009	.009	.010	.011
Lens Position Marker	.008	.008	.007	.008

APPENDIX IV

CAMERA MODIFICATION LAYOUTS

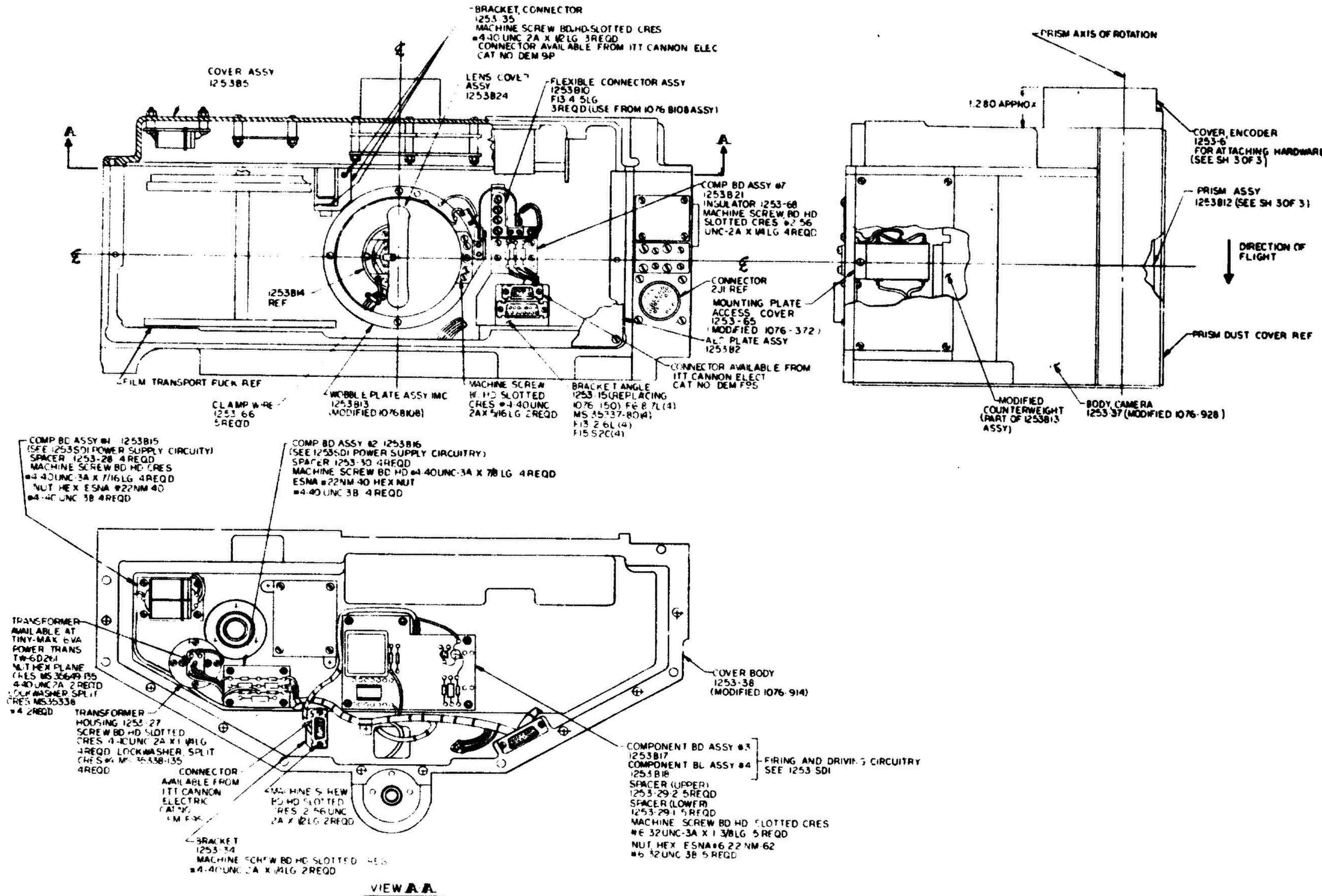


Figure 16. KA-56B MODIFICATION ASSEMBLY LAYOUT (Sheet 1 of 4)

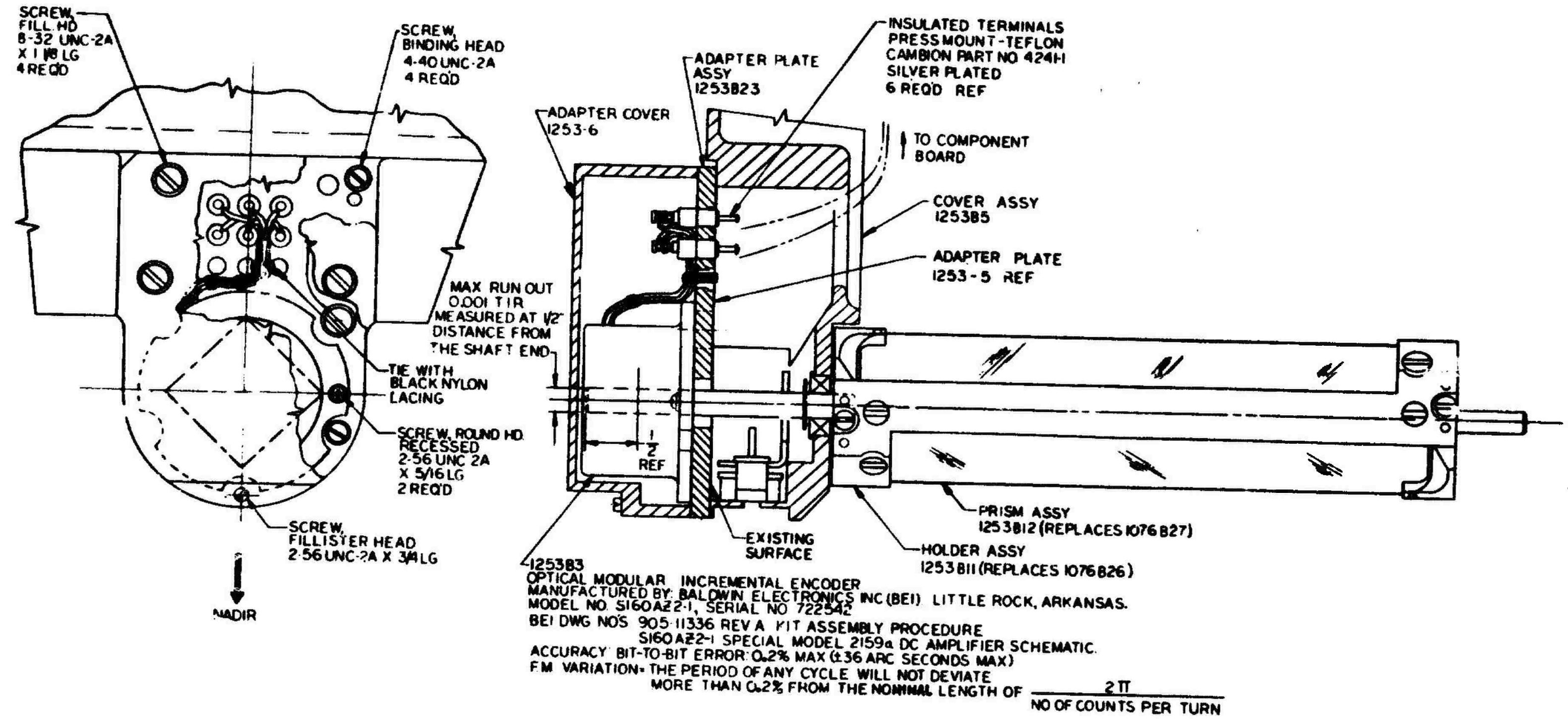


Figure 16. KA-56B MODIFICATION ASSEMBLY LAYOUT (Sheet 2 of 4)

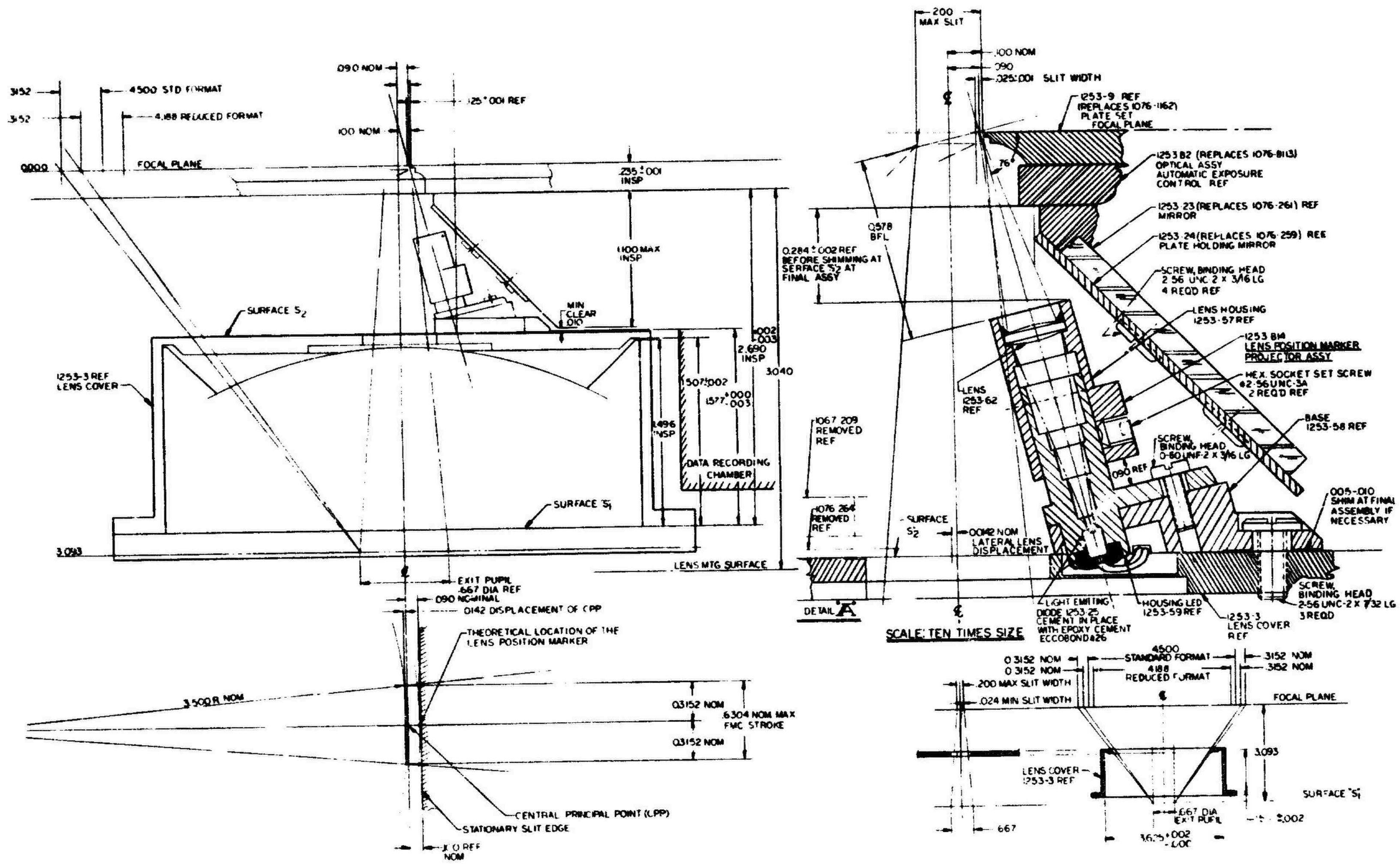


Figure 16. KA-56B MODIFICATION ASSEMBLY LAYOUT (Sheet 3 of 4)

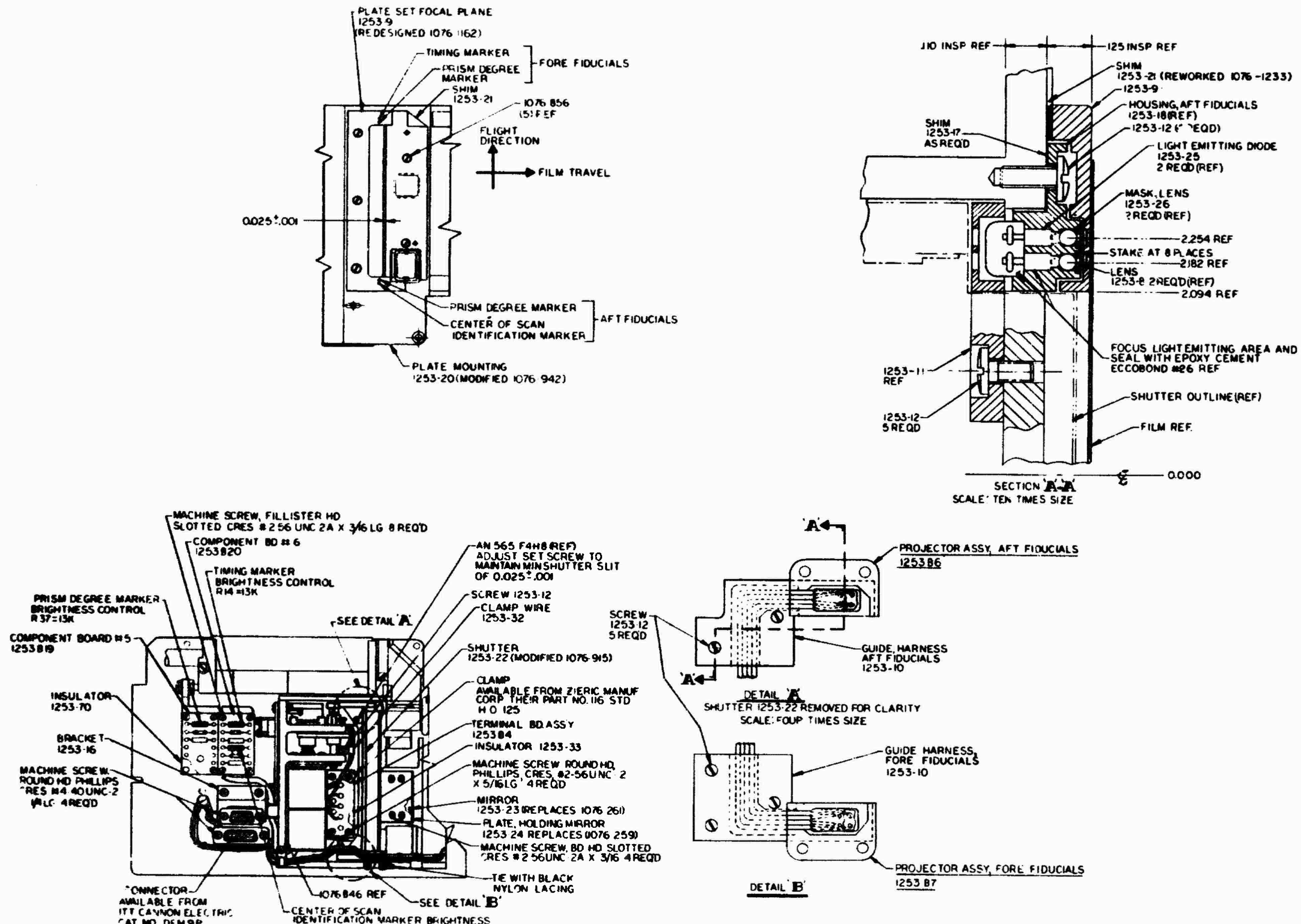
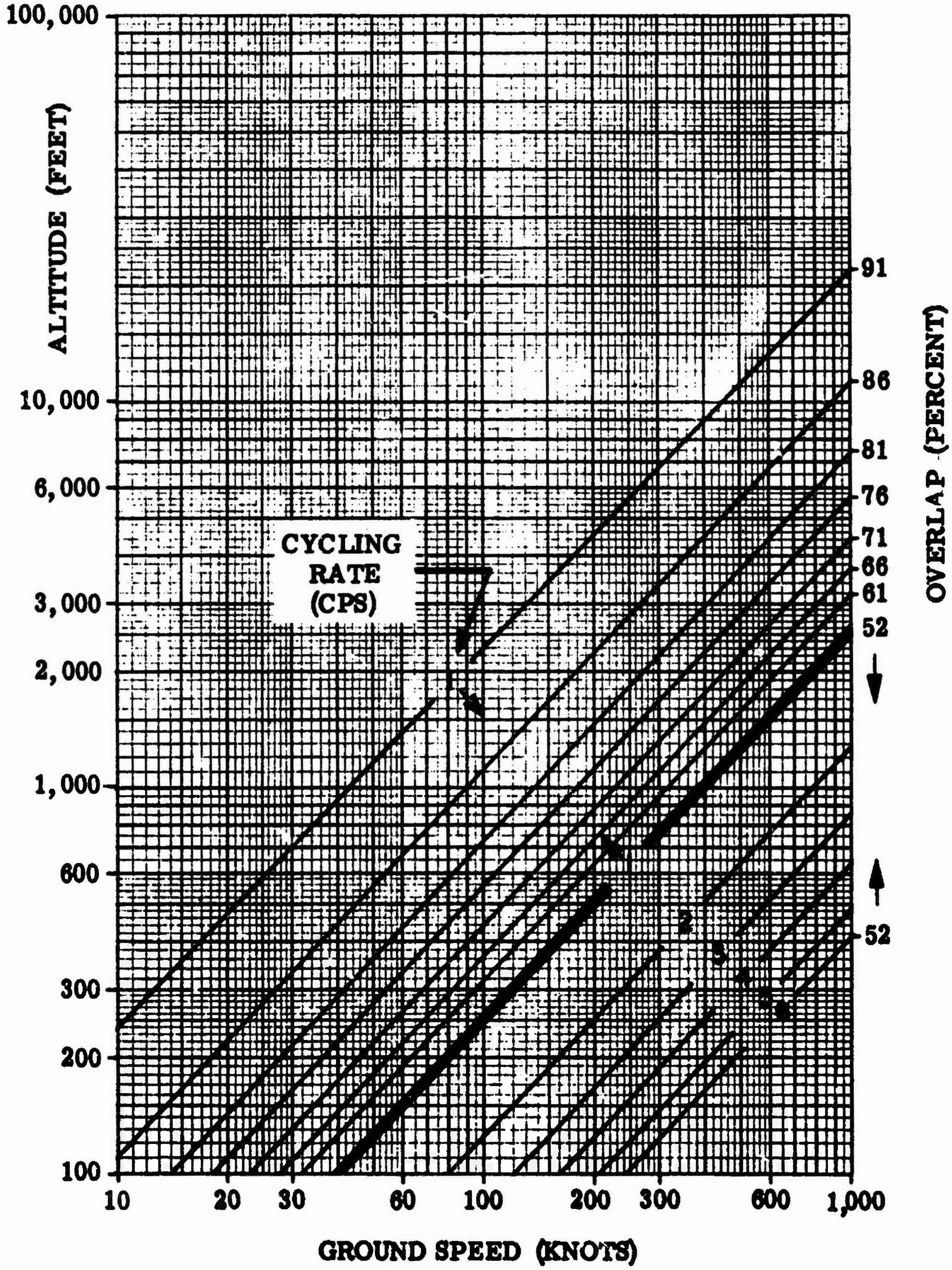


Figure 16. KA-56B MODIFICATION ASSEMBLY LAYOUT (Sheet 4 of 4)

APPENDIX V

CAMERA MODE SELECTION AND OVERLAP CHARACTERISTICS



*U.S. GOVERNMENT PRINTING OFFICE: 1973-713-122/44